DOCUMENT RESUME

ED 209 197 SP 018 968

AUTHOR Koerner, James D., Ed.; And Others
TITLE The New Liberal Arts. An Exchange of Views. An Occasional Paper from the Alfred P. Sloan Foundation.
INSTITUTION Alfred P. Sloan Foundation, New York, N.Y.
PUB DATE Aug 81
NOTE 84p.

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *College Programs; Curriculum Development; *Educational Planning; Educational Trends; Futures (of Society); *General Education; *Higher Education; *Liberal Arts; Obsolescence; Private Financial Support; Social Change; *Technological Advancement

ABSTRACT

The position taken by Stephen White, of the Alfred P. Sloan Foundation (New York, New York), in the title article of this collection, states that the programs of many liberal arts colleges are moving toward incorporating applied mathematics and technological literacy into the curriculum. White also states that colleges should be adjusting their curriculum according to the demands of an increasingly computerized era. He suggests that a program to support this development be studied at the Alfred P. Sloan Foundation. Responses to this position were solicited from the following educators and deans: (1) Elting E. Morison, Massachusetts Institute of Technology; (2) Gaines Post, Jr., University of Texas, Austin; (3) James L. Adams, Stanford University; (4) George A. Drake, Grinnell College; (5) Dick Netzer, New York University; (6) Jacques Barzun, Columbia University; (7) Peter Caws, City University of New York; (8) Donald L. Kreider, Dartmouth College; (9) Frederick Rudolph, Williams College; and (10) Richard Warch, Lawrence University. The responses deal with analytical thinking, the role of colleges and social change, the appropriateness of the title of the essay, and computers and mathematics in liberal arts programs. In a brief afterword, White reviews and discusses several points made in the responses, noting that four contributed positive suggestions and that many criticisms were baffling or irrelevant. (FG)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED209197

The New Liberal Arts

AN EXCHANGE OF VIEWS

An Occasional Paper from the Alfred P. Sloan Foundation

Stephen White
Elting E. Morison
Gaines Post, Jr.
James L. Adams
George A. Drake
Dick Netzer
Jacques Barzun
Peter Caws
Donald L. Kreider
Frederick Rudolph
Richard Warch

James D. Koerner, Editor

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

✓ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

SP018968

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

James D. Koerner

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

The editor, James D. Koerner, is a vice president of the Alfred P. Sloan Foundation.

ALFRED P. SLOAN FOUNDATION
630 FIFTH AVENUE
NEW YORK, N.Y. 10111

Contents

		Page
Foreword		v
The New Liberal Arts, by Stephen White, Director of Special Projects, Alfred P. Sloan Foundation		1
Responses		
1.	Elting E. Morison, Professor Emeritus, Massachusetts Institute of Technology	13
2.	Gaines Post, Jr., Department of History, University of Texas, Austin	18
3.	James L. Adams, Associate Dean of Engineering for Academic Affairs, Stanford University	26
4.	George A. Drake, President, Grinnell College	32
5.	Dick Netzer, Dean, Graduate School of Public Administration, New York University	36
6.	Jacques Barzun, University Professor Emeritus, Columbia University	39
7.	Peter Caws, Professor of Philosophy, Hunter College and the Graduate School, City University of New York	46
8.	Donald L. Kreider, Chairman, Department of Mathematics, Dartmouth College	54
9.	Frederick Rudolph, Mark Hopkins Professor of History, Williams College	61
10.	Richard Warch, President, Lawrence University	66
Afterword		
	Stephen White	72

Foreword

The occasional papers published by the Sloan Foundation in the past, with a few exceptions, have reported on programs already completed, on how monies were spent and what was achieved. One of the exceptions was a paper titled "The Teaching of Expository Writing," published in December 1977. That paper looked forward rather than back; its purpose was to provoke debate about a serious failure in American education and at the same time help the Foundation's staff explore the possibilities of a new program. In the end, we decided against a program in writing, but the occasional paper, which proved popular far beyond our expectations, stimulated a great deal of useful discussion. Our purpose in the present occasional paper is similar: to make a modest contribution to the discussion now taking place on many campuses about the undergraduate curriculum and the requirements for the bachelor's degree, and to elicit a response from our readers in the hope that their comments will help us design a new program at Sloan.

The subject of this occasional paper is the place of quantitative study in a liberal education. A word may therefore be in order concerning the title of the paper and of the first essay in it: like many titles, this one sacrifices precision to economy and perhaps audience appeal. We believe that quantitative skills are central to any education that could be considered liberal today, but we do not imply that they are the only "new" subject around or even that they are the most vital part of the liberal arts. We mean only to say that the quantitative side of the curriculum, long neglected, has today assumed a new importance that has yet to be reflected in the course of study of a great many undergraduates, perhaps most.

The first essay in this occasional paper, by Stephen White of the Sloan Foundation's staff, sketches the background of our interest in quantitative skills. In January 1981 the Foundation sponsored a small conference on "technological literacy" — that is, on the teaching of engineering concepts and methods to non-engineering undergraduate students. After that conference, Mr. White wrote "The New Liberal Arts" as an internal memoran-

dum that expanded the notion of technological literacy to encompass other kinds of quantitative skills such as computing and applied mathematics. It then occurred to us that if the paper were revised to make it a public document, it could serve as the opening piece in an occasional paper that would also contain the comments of others on the same set of issues. The Foundation is grateful to those who contributed to this paper. Our invitation to them was stated in general terms, asking them to react to "The New Liberal Arts" in whatever way they chose. As the reader will see, they chose a number of different ways.

In writing his essay, Mr. White attempted to make the case for quantitative study without allowing himself to be seduced by secondary questions of practicality. We realize that institutions seeking to carry out our recommendations will be faced with a plenitude of problems; financial, philosophical, political. Substantial changes in the undergraduate curriculum are always troublesome, particularly at a time of contraction in the educational system rather than expansion. William G. Bowen, writing his report as president of Princeton University in March 1977, remarked that,

> There always has been argument over what ought to be included and what can be excluded from a liberal arts curriculum, and the surest way to guarantee a long, disputatious, unsettled and unsettling faculty meeting is to bring to the floor *any* proposal for a change in the nature or content of the requirements governing the undergraduate program.

Yet that is exactly what we would like to do. We would like to put on the discussion agenda of colleges and universities the proposition that it is no longer defensible for them to turn out students poorly equipped with the quantitative skills they will need for the rest of their lives as individuals and citizens. We hope the debate will not be "long, disputatious, unsettled and unsettling," but will not be surprised if it is. Whether or not it is, the debate needs to take place. If the thesis of "The New Liberal Arts" is ultimately accepted by some significant number of institutions, the Sloan Foundation might be able to help them get on with the hard work of trying to do something about it.

For Sloan, that work will probably begin, if there is to be a new program at all, with liberal arts colleges, even though the majority of undergraduates are no longer found in these institutions. Given the Foundation's resources, concentration is necessary; but in addition, the liberal arts college remains the only institution whose sole purpose is to offer a liberal education. One might wish these colleges did their job with less uniformity than is customary, and this may be an opportunity for Sloan to encourage

variety. As Mark Van Doren said in the preface to his classic study, *Liberal Education*

> Any college can be better than it is; but all colleges would be better if those in charge of them considered together, at regular intervals, the ideal college curriculum. They would not need to fear that every college would then become identical with every other; such identities do not exist in nature. But if all liberal arts colleges had the same aim, and if they were serious in pursuit of it, the differences among them would become, for a change, really interesting.

One of these "regular intervals" seems to have arrived. The present cycle of re-examination of the curriculum in which many colleges are now caught up may be one means of increasing variety rather than uniformity among them. Neither the Foundation nor the colleges know how best to pursue the goal of quantitative literacy; it will take a lot of experimentation.

JDK

August, 1981

The New Liberal Arts

STEPHEN WHITE *Director of Special Projects*
Alfred P. Sloan
Foundation

So long as there have been societies, there has been the notion of acculturation — of a process by means of which each generation will be made acquainted with the culture it shares and prepared to enjoy within that culture a rewarding and an enriching life. The manner in which that acculturation is sought has changed over time, but for a good many centuries it has come to be called a "liberal education." Its salient characteristic lies in serving the inner being of the individual and the spirit of his society rather than their material needs; its rewards are neither of the kind that can be heaped and hoarded nor of the kind that must be consumed and renewed. At its heart lies the human urge to understand the world in which the individual finds himself rather than the animal need to exert some kind of control over the world.

There are none the less relations between the forms of liberal education and the manner in which a society assures its physical survival, as well as the success with which it manages to do so. In a materially impoverished society the needs of the body are likely to take priority over the needs of the spirit, and a liberal education is a privilege reserved for a fortunate few or gained at great price by a handful who cannot bear to live without it. In our own society with its accumulated wealth such an education has come to be in principle if not quite yet in fact a universal entitlement, available to all who reach out for it and in general a conventional conclusion to formal education or a conventional interlude before proceeding to professional education.

The association between liberal education and the form of the society that provides it is in another dimension no less fundamental. If it is the goal of a liberal education to provide an acquaintance with the culture in which it is embedded, then the nature of liberal education must evolve as the culture itself evolves. Within a single society at a moment of time a

satisfactory definition of liberal education can perhaps be put forward, but that definition becomes less and less satisfying as one moves from one society to another, and less and less relevant within its own society as the years pass. Such an evolution is an integral part of the history of liberal education in western cultures. For the Greeks and Romans, the liberal arts (as contrasted to the "servile" or "mechanical" arts) were first grammar, rhetoric and logic, to which were subsequently added arithmetic, geometry, music and astronomy. Much of this fell away during the centuries of poverty and disequilibrium that followed the barbarian invasions of Western Europe, and when the struggle to recover stable societies began to gain ground it was understandable that a liberal education should come to be defined as a close acquaintance with the classics.

Change came slowly; as recently as the last century the largest part of a liberal education was classical history and classical literature and classical philosophy, intermingled with what might be called classical theology. A scholar who spent his life at Oxford said of the University that when he first knew it, in mid-century, it appeared to be characterized by the belief that "all knowledge was shut up between the covers of four Greek and four Latin books," and Ralph Waldo Emerson wrote that "Oxford is a Greek factory." American colleges were somewhat less rigid; the American temperament created urges toward practicality, but the mid-century college experience has been described as ". . . the college chapel . . . the dying but still socially respectable and useful classical course of study, the capstone course in moral philosophy that was its great glory, and the extracurriculum with which students took charge of their own education." And in 1846, when Professor Evert M. Topping of Princeton was so bold as to suggest that Greek could be dealt with as a literature as well as a language, he was quickly brought to heel by the president, and shortly thereafter his resignation was gratefully accepted.

Evolution has been more rapid in recent years. Entirely new fields of study have penetrated the liberal arts curriculum in the United States; the behavioral sciences made their way into the curriculum and in some instances may be said now to dominate it; the study of history has given way to "American studies"; the study of literature to "creative writing" or "communications." There has been moreover a constant oscillation between the notion of a general liberal education and of a highly organized educational pattern in which one academic discipline or two are intended to be the focus of each individual student's efforts. There are periods in which the urge to reform is quiescent; in the last few years it has begun to reassert itself, with such prestigious undergraduate colleges as those at Harvard University and Stanford University in the forefront.

At the same time, barriers to evolution have become more formidable. It is a hard fact, reluctantly confronted, that remodeling a curriculum inescapably implies remodeling a faculty. When the culture itself changed slowly, and when liberal arts education itself was a modest enterprise, evolution could take place almost imperceptibly and almost painlessly. To put the matter with perhaps indecent brutality, professors then became extinct at about the same pace as the courses they taught. Today change, if it takes place at all, takes place a good deal more violently. And there is also a present singularity that is highly consequential: for the time being higher education faces a period of shrinkage for a wide variety of reasons, demography only one among them. Evolution during a period of attrition is never painlessly effected, and cannot be casually undertaken.

II

The graduate who gracefully accepts his first sheepskin faces a world much altered from the world his father faced. There are innumerable manners in which that change can be characterized, and in the light of the source and the purpose of this paper a somewhat parochial approach may be forgiven. The change that is now affecting liberal education is just the change that Alfred P. Sloan, Jr., perceived to be affecting management education in the years directly following World War II.

Mr. Sloan had lived through a period in which the analytic triumphs of science and technology were more and more rapidly transforming engineering practice. He had come to believe that analytic developments in economics and to a lesser degree in other behavioral sciences held the same promise for management practice. It is important to emphasize that it was not the practices of science and technology nor the products of engineering that stimulated that perception but the modes of thought represented in science and technology and effectuated in engineering. Nor did Mr. Sloan ever come to believe that analytic skills were of themselves sufficient. But he was richly aware of the intimate linkage between creative analysis and creative synthesis over an important range of human endeavor, and he wished to see that range extended to include his own profession. Mr. Sloan would have been the last man in the world to deprecate the "art of management"; at the same time he was anxious to see it reinforced with a "science of management" and in time a "technology of management."

What he could not have been expected to realize was the explosive speed with which the range of analytic skills would grow. There are many kinds of analytic skills, but perhaps the most powerful involve the reduction of complex phenomena into hard atomic data and the consequent

comprehension of the relationships among those data. In certain fields of endeavor, and particularly those fields in which the behavior of men and women individually and collectively is a critical element, the relationships among data grow exponentially as great masses of data pour in upon the observer, and the data themselves offer many levels of complexity. The task of analysis threatens to become overwhelming, and at best analysis has been until recently hopelessly crude. More often than not, a profound analysis simply could not be undertaken.

All this was changed, almost overnight, by the computer. Crudely speaking, the computer is beginning to do for the mind of man what the engine did for the muscle of man. The engine permitted man to manipulate matter in great bulk and at great speed; the computer permits man to manipulate data with the same extraordinary facility. Those who first developed the computer saw the promise at once: it would enable them, for example, to deal with the enormous mass of data necessary to understand and predict weather patterns, and even held out promise that weather predictions would be forthcoming before the weather actually arrived and not after. More rapidly than could have ever been anticipated, even broader uses for the computer, far outside fields that were ordinarily thought to be responsive to technological advance, were discovered by scholars whose data were the data of literature, or cognition, or history. Abruptly, all those who earnestly sought understanding came to recognize that they now possessed a powerful new tool which, like all important tools, was more or less indifferent to the purposes for which it was being used.

To be sure, certain fields of endeavor — and among them fields that are most important — were not directly affected. The poet, the artist, the mystic, the lover, are not in any comparable sense aware of the data with which they deal; indeed, the word itself is in all likelihood inappropriate. But they do live in the world like the rest of us and they, too, have been affected by the computer revolution, although few would be able to say exactly how.

It is perhaps important, even this early on, to preclude a misapprehension that is too easily generated. What is being considered here is the computer as one of the most powerful tools that has ever been brought into being for the service of the individual who seeks to understand his world and the way it wags. Like writing, it is a technology of thought. This note will not go on to propose that all students should be converted to master computer operators, any more than one would propose that all students be converted to expert calligraphers or masters of English prose style. It will, in time, propose that students be acquainted with the computer in some reasonably respectable fashion, which is surely no more

radical a thought than the proposition that they should be able to read and write.

But the central point is a quite different point. What the computer has done, quite beyond helping with airline reservations, is provide scope for analytical skills that has never before existed, and in so doing it has altered the world in which the student will live as well as the manner in which he will think about the world. It is these basic facts that constitute the link between the computer and a liberal education.

III

This note has dealt somewhat loosely with the notions of "analytic skills" and "technology." Indeed, the usage has been somewhat unconventional, being in the first instance somewhat more narrow than the general usage and in the second instance perhaps more broad.

Etymologically, for what that may be worth, and historically "analysis" denotes the process of reducing a complex state of affairs in one way or another to its simplest and in some sense irreducible elements. "Chemical analysis" is a familiar example, and all the more instructive in that what is nominally irreducible to an organic chemist may appear extremely complex to the physicist. But the word is perhaps more often used in manners that are in effect metaphorical: the analysis of a chess position, for example, is not reductionist in the ordinary sense of the word, and "psychoanalysis" may wander even further from the hard technical usage.

The phrase "analytic skills" is being employed here as shorthand for the kind of analysis that employs certain mathematical skills and that derives from mathematics a prodigious power. Those skills are not the skills of the pure mathematician, although they may employ the fruits of pure mathematics much as technology employs the fruits of pure science. They are constituted of two parts, not entirely distinguishable: mathematical modeling, which seeks to reduce a complex situation to a state in which it lends itself to mathematical manipulation, and that manipulation itself, which is almost always the manipulation of numbers. None of this is pure mathematics: it is the practical application of pure mathematics. In certain fields, analysis is almost totally reliant on a process of that sort; indeed, theoretical physics at one time was simply denominated "applied mathematics." In other fields, such as sociology, it is only a part of the analytic process, but it can be a most important part and, properly performed, perhaps the most reliable part.

The word "technology" is almost always associated with science and engineering, and for more than a century has come to constitute the bridge

between those two quite different enterprises. It employs scientific knowledge and the techniques of scientific analysis as part of an organized process that eventuates in the creation of new products, material or conceptual. It was scientific research that uncovered the details of the behavior of electrical currents in slightly impure silicon crystals. It was technology that investigated the possibility of employing that behavior to govern the flow of electrical currents at speeds and efficiencies that had previously been unimaginable. It was engineering, finally, that made it possible to produce the silicon chips and the integrated circuits that have become commonplace to the point where each of us is surrounded by them and in one way or another makes use of them daily.

What has happened in recent years in the behavioral sciences is closely enough analogous to that process to warrant use of the term "technology" in a broader sense. "Cliometrics" employs the techniques of history to isolate data that can be modeled mathematically and manipulated mathematically, and the result is a significant contribution to historical scholarship: it would not be unreasonable to call cliometrics a technology of history.

The ability to cast one's thoughts in a form that makes possible mathematical manipulation and to perform that manipulation, coupled with the ability to conceive the fruits of that analysis, are modes of thought, and there is evidence all around us that in making use of those modes of thought one may think with enormous new efficiency. But it is thinking itself that is the creative element: thoughtless modeling, and thoughtless computation, impressive as it may be, are devoid of real significance; thoughtless technology is at best ludicrous and may be actively destructive, as any other kind of thoughtlessness may be destructive.

And it is precisely as modes of thought that they become essential in higher education, and above all in liberal education. It has always been the purpose of a liberal education to provide an acquaintance, at least, with modes of thought, and even beyond that the beginnings of some degree of mastery over one or more of those modes of thought. The man with a truly liberal education is one who is aware of many modes of thought and aware, too, of the manner in which they interact among themselves and with the larger purpose of becoming a useful and a fulfilled human being.

It was considerations such as those which stimulated C.P. Snow's complaint and charges some 30 years ago in his essay on "the two cultures." He spoke there of the necessity for a truly cultured man to become acquainted with the second law of thermodynamics as well as the plays of Shakespeare and that phrasing, colorful and immediate as it may have been, perhaps concealed his true meaning. The central point was that humanists in broad terms organize their thinking in one fashion and scientists—to which may

be added technologists and engineers — in broad terms order theirs in another, and that a truly educated man owed himself an acquaintance with all powerful modes of thought. The Shakespearian canon and the laws of thermodynamics themselves are artifacts, each in its own way among the most glorious artifacts that the mind of man has produced and neither more humanistic than the other, for it was humans who created them both.

To believe, in this era, that a man possesses a liberal education who is ignorant of analytic skills and technological skills is to make a mockery of the central concept of liberal education and to ignore the nature of the world in which the graduate will live, and to which he hopes to contribute in one way or another. It is hard for liberal arts education that its revolution appears to be coming from without, but it would be fatal to pretend that the revolution is not upon us. The top rung of undergraduate colleges has already begun to move. Harvard and Stanford, as earlier noted, have each conducted a thorough revaluation of what they conceive to be a liberal education. Both universities in restating their requirements for an undergraduate degree have recognized in one fashion or another the needs that are set forth in this note, and both have recognized that there is much to do before those needs will be met.

IV

The ancient Britons, it was once suggested, painted themselves blue each year because they had painted themselves blue the year before. It is the deplorable fact that colleges and universities are prone to the same mindless dedication to ritual; so too are private philanthropic foundations. But changes ultimately arrive, not always by design.

Over the years, the bulk of support made available by the Alfred P. Sloan Foundation has been directed toward the country's major universities and toward research institutions. In the decade of the 70's, for example, grants totalling $133 million were made, of which $114 million or 88 percent could be so categorized. The balance was scattered among a wide range of recipients. Liberal arts colleges in particular were but modestly supported, the only significant activity being represented by a limited extension of an earlier program for the support of science education in liberal arts colleges, to which about $1 million was committed during the decade.

The neglect of liberal education was a consequence of the general design of the Foundation's program. The largest portion of that program is directed toward the provision of support for the hard sciences, technology and engineering. The hard sciences and mathematics have never been considered the major business of the liberal arts college, but in a few of those institutions one

or more of those disciplines had something better than a foothold, and the Foundation sought, with only limited success, to encourage those few and to increase their number. Technology and engineering were for the most part entirely outside the range of liberal arts colleges.

The balance of Foundation funds had been allotted to economics research and management education. The first is clearly the business of the major research universities. Management education, as conceived by Mr. Sloan, was intended to be graduate education and as we have noted was seen to be far more analytic than was the general fashion of the time, calling in particular for mathematical skills not ordinarily fostered in liberal arts colleges. It was not an accident that the first Sloan School of Management was founded at the Massachusetts Institute of Technology. Mr. Sloan did not merely intend to support management education; he planned to change it and in large measure he succeeded, as during his earliest years at General Motors he had succeeded in changing management practice.

In short, the neglect of liberal arts colleges, for such it has been, was not a decision in its own right but the consequence of broader decisions intended to frame a coherent pattern of action for the Foundation. It spared that small minority of liberal arts colleges which concentrated a significant part of their attention upon the fields in which the Foundation was active: Dartmouth College, for example, has always been among the leading beneficiaries of Foundation support, and although most of that support has been to graduate management education and engineering education, much has been allotted to the liberal arts undergraduate college. But the overwhelming majority of the liberal arts colleges, including the most prestigious, did not look upon the Sloan Foundation as a likely source of assistance, and lost little or nothing by so behaving. Their fund-raising efforts were far more profitably directed elsewhere, among that great majority of foundations whose principal interests coincided with their own.

For the Sloan Foundation, a perception of the desirability of some change in its customary pattern of activities flowed from those activities themselves. Higher education in science, technology, engineering, economics and education for the public service have always been considered by the Foundation to be primarily vocational in the best sense of that much-misused word, although an awareness of the humanistic element in pure science stimulated the limited involvement with the liberal arts colleges in the 60's and 70's. The earliest involvement with public management in the 70's was also primarily vocational, and was stimulated by the very considerations that are the central matter of this note: the need for analytic skills and technological literacy in the preparation of students for the public service.

Once the entry had been made into the support of education for the public service—and it was a major step, in which the Foundation has so far invested $11.3 million—there immediately followed a recognition within the Foundation that since all citizens are involved, however remotely, in the public service some kind of education in public policy analysis and the technological aspects of analysis could be construed to have a place in the liberal arts curriculum. As a consequence, grants totalling $2.4 million were made during 1977-1979 for undergraduate programs or the planning of such programs, at Dartmouth College, Duke University, Lawrence University, the Massachusetts Institute of Technology, the University of North Carolina at Chapel Hill, Oberlin College, Occidental College, Stanford University, Swarthmore College, Tulane University, Washington University, and Williams College. Those grants are for the most part still active and it is too early to say with confidence what their outcome will be; some, at least, seem even now to be most promising.

During 1980, there were two further developments, each of which can be attributed in part to the program in education for the public service. Students entering that program at the graduate level, which was where the Foundation's interest was principally focussed, far more often than not arrived ill-prepared in mathematics and almost totally ignorant in technological modes of thought. That fact had sensitized the officers of the Foundation to the inadequacies of undergraduate education, as this paper has sought to state them. As a consequence, the Foundation itself began to consider steps it might take to promote what it called "technological literacy," made several modest grants, and early in 1981 convened a brief meeting of interested academics to consider the matter further. A report on that meeting has been prepared: in brief, that report recommends that the Foundation undertake major activities in that area.

At about the same time, an inquiry was received from Case-Western Reserve University, asking if the Foundation might provide support for curriculum reform in applied mathematics, at both the undergraduate and the graduate level. The Foundation replied with a counter-proposal: that Dr. Gail Young, who had initiated the inquiry, and the University convene a meeting of applied and pure mathematicians to deal with the problem of applied mathematics in higher education as a whole rather than Case-Western Reserve in particular. Both the University and Dr. Young responded warmly. The meeting will take place in late June of 1981; applied mathematics at the undergraduate level will be high on its agenda.*

*In the event, this conference, which took place as scheduled in June 1981, did not address the question of applied mathematics in the education of undergraduates not majoring in mathematics. Although the conference was eminently successful in examining the mathematics major at both the undergraduate and graduate level, the discussions had limited relevance to "the new liberal arts."—Ed.

What has happened, in the eyes of the Foundation, is not so much that the Foundation has moved into the domain of the liberal arts colleges but that the liberal arts colleges, whether they know it or not and whether they welcome it or not, are moving into the domain of the Foundation. This paper makes that case in the belief that the undergraduate policy studies program, whatever else it may achieve, exposed to the Foundation itself the recognition that the Foundation had been lethargic in altering its own perception of higher education and in recognizing the revolution that must take place in liberal arts education.

Lethargic as the Foundation may have been, it would be unrealistic to ignore the fact that the liberal arts colleges are likely to be more lethargic still, and that what the Foundation may recognize as an opportunity and indeed an obligation, the bulk of the liberal arts colleges will perceive to be a threat. That very fact makes the obligation that lies before the Foundation the more pressing, even while it makes its execution more difficult. Yet the conversations that officers and staff have lately held with representatives of the liberal arts colleges, and particularly the better liberal arts colleges, have made it clear that the Foundation will not be without powerful allies. The task will be in the pattern of earlier major Foundation undertakings (and Mr. Sloan's own intervention in management education). The very strongest institutions, assisted by the Foundation, will lead the way; in time others must ultimately follow.

V

If it is conceded that a persuasive case has been made, it still remains necessary for the Foundation to determine the procedure it will follow that will most effectively further the aims set forth or implied in this paper.

From what has been written here, it seems to follow that the program must be organized in terms of the liberal arts colleges and not of the separate disciplines. The changes that should occur will be taking place in the college as a whole; they will affect not only the offerings of the liberal arts curriculum but the very conceptual basis of the liberal arts curriculum. Courses in applied mathematics cannot be regarded as something added to an established curriculum; they must be seen to lie at the heart of the curriculum, and must make the same claim on the college as a whole as courses in philosophy or government or literature or languages. Indeed, since resources are not infinite, the definition of a new liberal arts curriculum must in some degree imply changes that will be resisted within the college and can be put forward only by the separate institutions in their institutional roles.

Given the size of the total problem, and the great number of undergraduate colleges that must ultimately be involved, it is clear that the Foundation can do no more than help generate momentum, for the whole task is certainly beyond the Foundation's means. What appears called for is an intensive effort over a period of five or six years, defined with some precision and endowed with some coherence. The undertaking meets in all its aspects the criteria for a Particular Program as the Sloan Foundation defined that part of its operating procedure more than 10 years ago.

Two elements of such a Particular Program are now being shaped in the efforts only now under way in applied mathematics and technological literacy. A third element presents itself at once: it deals in broad terms with the computer.

The computer stands in an odd relationship to applied mathematics and technological literacy. Looked at from one point of view, the computer *is* applied mathematics; looked at from another point of view it is a glorious technological achievement. It represents in itself the close relationship between analytic skills and technology: the best way to discover what a computer can do is to know how it works; the best way to discover how it works is to know what it can do. It lies at the crossover between the two modes of thought, enriching and enriched by both.

Inevitably those who deal with applied mathematics must deal with the computer, as must those who deal with technology. But the computer is worth dealing with in its own terms, and to do so will require an enormous amount of curricular invention.

It cannot be too often stressed that the purpose is not to turn out from the liberal arts college hordes of applied mathematicians and technologists and computer scientists, any more than it was earlier the purpose to turn out hordes of philosophers and historians. The purpose has not changed: it is to turn out civilized adults, a few of whom will inevitably become applied mathematicians and technologists and computer scientists and philosophers and historians, most of whom will not. But no adult is truly civilized unless he is acquainted with the civilization of which he is a member, and the liberal arts curriculum of fifty years ago no longer provides that acquaintance. The fact that it does not do so is reflected by the fact that one can no longer study even philosophy or history at a respectable scholarly level without some acquaintance with the modes of thought represented by analytic skills and technological skills. A civilization, a culture, does not readily divide itself into distinct academic disciplines.

The Foundation has never entered lightly into a Particular Program, and the officers and staff would not propose that it do so in this instance. Rather, we now intend that a process be begun of canvassing leaders within

liberal arts education, in part to sharpen our own views, in part to discover whether there is a significant constituency for those views, in part to discover, as certainly as may be possible, whether the program that has been crudely sketched in this paper is a program capable of being realized in action. Only after those steps have been taken, and only if they meet with favorable response from the colleges and universities from which leadership must come, will the Foundation take steps to establish a Particular Program in Liberal Arts Curriculum—a challenging title, given the intentions.

RESPONSE 1

Elting E. Morison

Professor Emeritus
Massachusetts Institute of Technology

Mr. White's admirable memorandum proposes a new departure for the Sloan Foundation, which I hope it pursues and sticks with through thick and thin (of which there will be a good deal). Whatever I find to say is said in the hope that it may help a little with the work.

The first premise of the memorandum is that since the world (or a large part of it) is now a technical system the educational experience should provide instruction in how the machinery operates and what its capacities are. To this end college students should acquire appropriate skill in mathematics, learn to use the computer, and come to understand "technology." Concerning the end there can be no reasonable dispute, at least from me. As for the means selected I have the following few comments.

Obviously mathematics is the indispensable intellectual tool for dealing with the technical environment. Equally obviously a considerable number of students resist it, do badly in it or avoid it altogether. How to produce an appropriate level of competence in the generality of students remains a problem. The decision, therefore, to convene a group this summer to deal directly with this problem seems a necessary preliminary stage in the refinement of the Foundation proposal.

The memorandum is eloquently convincing about the significance of the computer. But its comments on how it can be made to fit into a college course of study do not go much beyond saying that students ought to have a greater opportunity to use it. That is no doubt true and it could be equally said of students all the way down the line to the first grade. It is another one of those things that in a better world kids could learn more efficiently and naturally before they get to college. This is a large topic and there is no need to pursue it here. But there does seem a need for a preliminary examination (as in the case of mathematics) of the place and meaning of this powerful instrument in the educational process with special reference to it both as a tool and as a subject for study (its understood potentials and its implications) in college years.

I have a little trouble with the definition of "technology" as put forward in White's paper and that definition is in no way rendered more precise by the offered analogy with "Cliometrics." I should prefer a description which includes all the elements cited (but distinguished from each other) in the chip example; that is an assumption that "technology" is a process that starts with research, proceeds through development, and ends with production. Put that way this process is the determining influence in the construction of our technical environment. It obviously deserves therefore careful description, analysis, and understanding. The idea of studying it in college years is, to me, novel and very interesting and, I think, should be actively pursued. But my peripheral experience with the process (which includes membership on a technical advisory board for a company that thinks of itself as middle-sized) leads me to believe that even a good many of those who try to manage the process couldn't describe it and don't understand it. It is not, after all, as the chip example reveals when pursued a little farther, an altogether stable and neatly laid out way of doing things. So I suggest as a preliminary stage the creation of yet another study group to supply the requisite content, method and philosophical depth for an extremely interesting and useful college course of study.

That, insofar as the memorandum deals with specific subject matter, is all I have to say — except that in that better world and even in this one, I would like to see both some physics and biology.

The second premise in the memorandum is that the proposed subject matter should not be left to stand alone in the undergraduate study; it should be brought into suitable connection and synthesis with other subjects to produce "a truly liberal education." College, in this view, provides a kind of cultural mapping; it is a trial run for students about to enter the surrounding culture — which is itself a device to establish ordering connection among the energies and interests within it.

That is what colleges in the great days used to be and what the memorandum suggests they might become again. There are, however, some formidable obstacles in the way. For one thing the present way of dealing with the body of knowledge is to split it up, and then work on the splinters. This has proved a successful way to expand the amount of information and advance careers but it works against an interest in connection and synthesis. Universities have refined this divisive process and colleges necessarily reflect its influence. So people working in the various compartments of learning have little experience in fitting things together and have lost, to a great extent, the sense of a various whole for what is known.

Then there is the nature of the particular subject matter proposed in the memorandum. A truly liberal education in the past was never under-

stood to include a knowledge of and feeling for the machinery—either the principles it rested on or its actual operations. "What," as Matthew Arnold asked, could "coal, iron and railroads have to do with sweetness and light?" This goes back a long way—at least to Plato and his invidious distinction between deep thinking and doing work. And it still persists. Harvard, as White says, has recently tried to rearrange its undergraduate education to bring it up to contemporary speed. After several years of discussion and negotiation it produced formulae that found a place for the study of the "life style" of Brazilian Indians but made little room for the kind of subject matter White has in mind.

And then there is the culture for which college is a trial run. Its structure as received from previous generations has proved an insufficient context for the regulations of the energies within it; it has not yet discovered satisfying answers for many of the questions posed by those energies; it has been unable, so far, to produce general agreement on a set of objectives for the use of those energies. So now there is a good deal of disorder in the system. The task of "acculturation" is complicated by the fact that there isn't much of a culture out there.

Such considerations have persuaded a good many people, including at least one U.S. Commissioner of Education, that colleges should give up their synthesizing and cultural mission and teach instead the methods of individual survival in a disjointed world — trades, vocational technique, professions. For some students this may be the best way out and, in the short run, it can be made to seem a prudent course for all. In the longer run, however, it would only continue the existing confusion. Somewhere in the educational process the work of connection must go on and colleges seem the most likely places to do it.

Some colleges have already tried to do it. But what they have achieved so far seems often no more than a rather arbitrary and bland rearrangement of what Whitehead called polite learning. There are lots of reasons for this. For one, there is the prevailing administrative policy that assumes that any modification must leave the individual departmental interests protected and undisturbed. A second, and far more important, is that colleges have not yet discovered a compelling organizing principle for bringing together all the divisions of learning.

A search for such an organizing principle may well wind up in that area colleges know least about—technology. One of the things about technology is that it creates situations that are without much useful precedent. That is the main reason why the received scheme of things has lost much of its binding power. It is also the reason why colleges, in the interests of

acculturation, can no longer simply distribute the cake of custom and transmit the best that had previously been thought and said in the world.

These novel situations created by technology are a determining characteristic of the society college students will soon enter. It follows, I think, that students in their college years should be exposed to these situations, and given practice in dealing with them. Put simply, they should learn what it takes to develop new, sustainable, civilizing contexts for the organization of the machinery and acquire confidence in their ability to make such contexts.

Somewhere in their course of study, in other words, they should become engaged in the unfinished business in the outlying society — the problems not yet solved, the questions not yet answered, the opportunities not yet followed through. Topics in these categories come in all shapes and sizes — posed by the new means for procreation, for the exploration of outer space, for the manufacture of energy, for the production of novel goods and services. Entangled with them are such various sub-topics as the nature of work and the work place, the university as a profit center, the possible limits or limiting of inquiry.

They all have their origin in technology—genetic engineering, nuclear reactors, the shuttle, servomechanisms and the computer, for instance. But they all lead out to every corner of human endeavor—economic arrangement, political structures, institutional design, communication networks, social organization and the condition of individual lives. They also raise for review the timeless concerns — the relation between thinking and doing, the boundaries of appropriate scale, the proper claims of aesthetics and the difficulty of choice among both practical and moral considerations.

Properly conceived, therefore, these topics contain all the different "modes of thinking" and all the diverse subject matter that should contribute to the operations of the modern world. The effort to understand the new situations dealt with in these topics and to reduce them to manageable circumstances (by creating civilizing contexts for the technical energies) must necessarily find ways to integrate and synthesize all the active variables in the particular occasions under study.

In such study the nature of an organizing principle for a truly modern liberal education will become clear — what one needs to know to understand the new situations existing in society and to reach resolving decisions on what to do about them. Acceptance of this principle would certainly require some changes in the conventional college way of doing things. This is not the place to suggest the modifications in any detail. But there is room for a few remarks.

A careful investigation of any of these topics would require time — maybe a year. And it would require also faculty members and students in different fields working together in a combined effort. Place must be found for those familiar with the technology and for those familiar with the study of men as individuals and political animals. And here I would urge the presence of those who proceed by the artistic impulse. Aesthetes, as the Greek discovered, can be a determining influence in the production of civilizing context. In this new kind of pedagogical exercise — which deals with new ways to do things — the creative energy in art may be as useful as the analysis of scholarship.

One other thought. The object of these exercises must begin with the desire to understand but must proceed in the desire to use what is understood to establish firm control. Technology is a more powerful means for shaping the future than men ever had before. It imposes the obligation — new to us — for wise management of the entire enterprise.

None of this may be of any particular help to the Sloan Foundation in its specific objective. But however the Foundation decides to proceed I have a concluding remark on tactics. The intent to seek the active support of the "leadership" institutions has obviously much to recommend it. But I suspect it will be very hard going. Those cited as "strongest" are universities. Although they are having some trouble deciding what a university is and should be today, it is at least clear that in their intellectual life they are drawing steadily away, if not from undergraduates, at least from the traditional aims of a liberal arts education.

More help, at least in the development of a new kind of program, will come I think from smaller colleges, and may be, especially, those in the middle west. And there is another place to look — to those institutions which have had historically a special interest in the kind of intellectual work with which the Foundation is most familiar. Of all the places I have some knowledge of the Worcester Polytechnic Institute has come closer to fulfilling the Foundation's design for a truly liberal education for today than any other. It may be that those who understand technology have a surer sense of what is now required for the ordering of the world, or at least a greater anxiety about it, than those who have done their work on the other side.

RESPONSE 2

Gaines Post, Jr. | *Department of History*
University of Texas, Austin

Many educators, national commissions, and employers advocate strengthening the undergraduate curriculum. As evidence of the need for change they cite inadequate skills among college graduates, the absence of a common cultural tradition, the proliferation of academic disciplines, and an arbitrary or anachronistic curriculum. Since the nineteenth century, liberal education has adapted to the vocational needs of students and to new fields or methods of inquiry while at the same time attempting to preserve some notion of a common educational experience that helps to socialize the individual. Emphasizing specific modes of thought and the need for social relevance, Stephen White presents a strong case for revising the curriculum to catch up to extramural conditions that he calls revolutionary.

White alludes to the thesis of two irreconcilable cultures, one humanistic and the other scientific and technological. I do not doubt that widespread acceptance of this view has done considerable damage to intellectual and social life on campus. In this essay, however, I should like to consider a different dichotomy, one which can be found in every major field of knowledge. I refer to the distinction between what might be called liberal knowledge and technical knowledge of a subject or method. By liberal knowledge, I mean that which is useful in many disciplines or professions, easily related to civic issues, and laden with questions of value. Technical knowledge, on the other hand, is of limited use beyond one or a few disciplines or professions, has no apparent civic relevance, and raises no questions of value.

Something like this contrast can be found in two recently published reports that have received national attention. In *The Humanities in American Life* (University of California Press, Berkeley, 1980) the Commission on the Humanities observes that the humanities provide useful analytical tools for examining concrete human problems and that new computer technologies can benefit humanistic research. The Commission's argument for learning scientific and technological literacy in our schools and colleges

rests firmly on normative considerations: citizens need to understand the characteristics of scientific inquiry and the functions of computers and other technologies in order to use science and technology humanely. Yet the Commission also states that the humanities have an integrity of their own; their methods are distinctive and their texts cannot always be related to contemporary issues.

In *Science and Engineering Education for the 1980s and Beyond* (Washington, 1980), the National Science Foundation and the Department of Education assert "that a deeper understanding of science and technology will become increasingly important to the ability of all Americans to function in their occupations . . . and in their roles as citizens." Yet this report faults interdisciplinary courses in science, technology, and society for failing to convey the "processes of science and technology themselves"; indeed, the report barely attempts to relate science, technology, and mathematics to social, moral, or aesthetic sensibilities—that is, to liberal education.

The contrast I have drawn between two habits of mind is an admittedly oversimplified elaboration of the antithesis that A. N. Whitehead called fallacious over 50 years ago: "There can be no adequate technical education which is not liberal, and no liberal education which is not technical; that is, no education which does not impart both technique and intellectual vision." (*The Aims of Education and Other Essays*, New York, 1929.) As we introduce new skills to liberal education, and indeed as we retain traditional skills, how can we insure that the learning of technique will also be liberal because it is "transfused with intellectual and moral vision?" White recognizes this central question, but I cannot infer a clear or reassuring answer from his discussion of the social purposes of education, the importance of method, and the politics of changing the curriculum.

I concur with White that liberal education should evolve as society evolves, and that what he describes as analytical and technological skills ought to be part of a liberal education. We encounter an increasing volume of information in our daily lives, yet most of us have little understanding of how informational technologies work and where they may lead. White mentions the computer revolution, and presumably his use of the term revolution elsewhere refers chiefly to rapid technological change. I doubt that he means to separate technology from important questions of value, but that is the impression left by his neglect of the social and moral implications of the technological revolution. How do differentiated skills affect the conditions of work, the fabric of social relations (including those between generations), the nature of politics, and the use of leisure?

The less we ask such questions and the more we emphasize society's demand for skills, the more likely we are to assign higher education a reactive role. That is, in response to society's needs, the college or university should teach certain kinds of skills that will be useful in certain kinds of jobs. Although White does not subscribe to such a narrowly utilitarian view, neither does he consider the formative mission of colleges and universities. Rather than simply adapt to public demands, these institutions must help students learn how to use technique critically and sensibly in as many professional and civic situations as possible. In brief, liberal education must help shape the public's definition of the educated or civilized person.

White's view of analysis is neither simply quantitative nor naively positivistic. Concerned with analytical skills of a reductionist and mathematical kind, he reminds us that computers provide unprecedented precision in dealing with large quantities of information and using certain kinds of analysis. One can sense in his paper the same uneasiness expressed at the conference on technological literacy sponsored by the Sloan Foundation in January 1981 — that we dilute the essence of any mode of inquiry when we study it in a general or interdisciplinary manner. Although I sympathize with this attitude (how instructive is a dash of historical method added to a business course?), I would criticize White's discussion of method because I believe it inadvertently undermines liberal education in two ways.

First, liberal education ought to look more closely than White has at the interrelationship of different techniques of inquiry. For example, humanists reduce data to decide what is the problem and what are the most effective means for examining it. This process may be analogous to mathematical modeling, although not usually accompanied by manipulation of numbers. Scientists, engineers, and humanists sometimes go back and forth between reductionist and inclusionary methods, between descriptive and interrogative statements, between analogy and actuality. Scientists and technicians sometimes look for complexity and nuance, humanists for simplicity and coherence. Educators frequently define critical thinking in terms of syllogism, yet there is increasing evidence that learning in the visual and performing arts can help raise levels of achievement in mathematics and other disciplines normally associated with deductive reasoning. Perhaps liberal arts colleges can find a common language as free as possible of jargon and arcane symbols, a language that will illuminate various conceptions of analysis, verification, and error. Whatever our degree of success in this search, the comparative study of methods encourages us to visualize the broader intellectual significance of any method and cultivate the kind of thinking that is indeed, to use White's phrase, "the creative element" in using mathematical computations.

Second, while White seems too ready to separate methods of analysis, he would appear too reluctant to recognize important differences between liberal and technical ideas of method. I am not convinced that thinking efficiently, one of the oft-cited advantages of new technologies, will necessarily mean thoughtfulness of the kind I have been calling liberal. Creativity in a liberal education encompasses more than the ability to see connections or divergences among methods; it means also critical reflection on the meaning of self, citizenship, and morality. Here the inclusiveness of evidence (historical and contemporary, plural and personal, spiritual and material) is of such importance that the reductionist virtues of mathematical method are minimal. Here liberal learning has — or ought to have — a greater tolerance for ambiguity than does technical learning. I disagree fundamentally with White's judgment that mathematical skills are needed in order to attain "a respectable scholarly level" in philosophy and history. Some very good philosophers and historians see respectability as freshness of imagination, clarity of language, and commitment to non-quantifiable discourse on age-old questions about individuality and community. If this type of scholar and teacher becomes extinct, so will liberal education.

The Sloan Foundation will have to confront political realities if it undertakes a new program on mathematical and technological literacies in the liberal arts curriculum. White reminds us, with a grim Darwinian notion of adaptation, that faculty often oppose significant changes in the curriculum. He correctly anticipates resistance from those who would feel threatened by placing applied mathematics, for example, at the core of the curriculum alongside courses already there in the humanities, social sciences, and sciences. Many humanists are suspicious of quantifiable proof. Many people not trained in the use of computers dread them. More generally, faculty in disciplines firmly established in the curriculum eye those who would intrude as presumptuous imperialists, especially if the latter represent methods identified with flourishing schools of engineering and business. But there is more at stake here than shares in a finite academic domain. White reaches the philosophical basis of liberal education when he invites a new definition of the liberal arts and change at the heart of the curriculum.

What are the essential characteristics of a liberal education? Or, to use White's term, what sort of "acculturation" ought liberal education to provide? Recently, the replies from liberal arts colleges have been neither forceful nor unanimous. If the answer is knowledge of major modes of thought, then faculty must determine which of these are most important for the late twentieth century, and which deserve critical mastery rather than mere acquaintance. Faculty may discard old methods to make room

for new. If they do not, then the liberal arts curriculum will continue to expand while many faculty claim on the contrary it should contract to boundaries of coherence that have been obliterated by flatulent course catalogs. As they consider how knowledge can be divided, faculty will discuss the relationship between analytical skills and factual content. They must select the subjects and teachers for core courses, plot distribution requirements, collaborate with deans, and so on.

The curriculum resulting from such political processes might incorporate White's proposal, and might be more or less coherent than the curriculum which preceded it. Whether it remained a liberal curriculum, however, would depend less on its particular mix of methods than on the spirit in which knowledge was taught and acquired. I do not view White's recommendations as revolutionary unless they should displace courses that enable students to interpret revolution. This ability requires literate and discerning participation in the life of the community; historical and aesthetic perception; critical awareness of the connections and dissimilarities among major fields of knowledge; informed judgment of how knowledge can be used or abused; appreciation of individual solitude and international interdependence. The liberally educated person exemplifies these qualities. Although White holds similar educational ideals, he probably underestimates the difficulty of preserving them in a curriculum based on technique, especially during a period when budget cuts and the public demand for useful skills discourage many educators—alas, even in liberal arts colleges—from endorsing the often intangible benefits of liberal education. The challenge for liberal arts colleges and the Sloan Foundation is no less philosophical than political, a fact that ought to direct curricular strategies toward insuring a liberal environment for method.

Notwithstanding the heterogeneity of American colleges and universities, I would emphasize the need for balance between courses in method, courses relating methods to civic issues, and courses viewing methods comparatively. The Sloan Foundation evidently prefers the first type, notably in applied mathematics, technological literacy, and computers. By concentrating on one method, the student can apply it more precisely in and after college than would be likely after taking general or comparative courses. At Dartmouth College, for example, computers are viewed as a new language, an understanding of which requires knowledge of a certain sequence of steps. Dartmouth's success (over 95 percent of all undergraduates use computers) may not be easily transferable to other colleges, for many faculty will resist the introduction of new methodological courses at the core of the curriculum, and students in some disciplines will avoid courses

th[at] they perceive to be so mathematical or quantitative that they are irrel[e]vant.

Courses of the second type, in science, technology and society (commonly called STS) have sprung up by the hundreds over the past decade, a fascinating example of the reciprocity between curriculum and public consciousness. The curriculum has responded to and helped inform public concern over the use of natural resources, the ethical implications of biomedicine and genetic engineering, and the impact of communications technologies on human behavior. In general, the aim of these courses is to connect science, technology, social conditions, and values; some have been jointly supported by the National Endowment for the Humanities and the National Science Foundation. At San Francisco State University, the "NEXA" program considers the convergence of the natural sciences, social sciences, humanities, and arts.

At the Massachusetts Institute of Technology, the "Program in Science, Technology and Society" offers a course on "Computer Cultures, Computation, and the Individual." The "Program in Technology and the Humanities" at Carnegie-Mellon University includes graduate as well as undergraduate courses. In the "Program on Humanistic Studies in Engineering," developed at Princeton University in the early 1970's, students from both engineering and the liberal arts examine the social and aesthetic criteria for design in structural engineering. At Worcester Polytechnic Institute in Massachusetts, the course "Light and Vision" interrelates science, technology, the humanities, and the arts during three major historical periods of transition. The "Program in Values, Technology, and Society" at Stanford University proceeds from the principle "that it is vitally important to obtain a broad understanding of technology and of its human and social implications."

I gather from White's paper and from the recent Sloan-sponsored conference on technological literacy that the Sloan Foundation is reluctant to fund programs of this second type, unless perhaps the emphasis is on technological literacy or analytical skills.* The Foundation might consider compiling a list of those examples that do stress method and persuading other programs to do so. It should be possible to help mitigate the tendency of STS courses to water down method without forcing them to weaken their historical or normative content.

*The Sloan Foundation has supported many types of STS courses and policy analysis courses (including the VTS program at Stanford). The present question is whether Sloan should now, in addition, support instructional programs whose main goal is quantitative literacy for undergraduates not majoring in science or engineering. — Ed.

The comparative study of method has been relatively unexplored by colleges and unsupported by federal and private sources. This type of course may provide fertile middle ground between the two mentioned above. One might add new analytical techniques to existing courses. This would probably be more difficult in the humanities and arts than in the sciences, social sciences, and mathematics, where quantitative methods are already used. In a history course, for example, students could develop a computer program and comprehensible quantitative data. Or one might develop new courses that examine specific problems with different forms of analysis such as metaphor from drama, multiple explanations of causality or personality from history and literature, the correlation coefficient from social science, and the computer program. Gerald Holton has described this route as "functional incorporation"; Clifford Geertz has called it "wary reasoning from analogy." The purpose of such courses would be to examine methods generally and comparatively, with or without relating them to questions of value, and to achieve some sort of synthesis of fields while at the same time preserving the methodological essence of each. Some STS programs, San Francisco State's, for instance, already include courses in comparative method. The Sloan Foundation might note such examples and encourage other programs to follow suit with special reference to the techniques outlined in White's paper. Although modifying existing courses would simplify the political problem of changing the curriculum, new courses independent of STS programs are also needed.

Major changes in the curriculum are practically impossible without strong administrative support for small groups of committed faculty. Outside sources of support can help provide the necessary time and incentives for faculty development. For example, workshops can teach faculty in the humanities how to apply basic computer skills to their courses in at least a modest way. More importantly for the college curriculum as a whole, I would recommend holding interdisciplinary colloquia on method. These might compare different meanings of error, plausibility, utility, and value. They might distinguish between method and mannerism, and between inclusionary and exclusionary forms of analysis. They might look for aesthetics in engineering and in mathematical formulas, logic in art, and fantasy in science. With careful planning, one consequence of such forums can be curricular change, especially if some of the best minds and strongest administrators are involved from the start. It would be useful if the colloquia themselves included discussion of the curriculum; one might argue for example that courses in a single technique can be taken in the freshman or sophomore years, whereas the comparison of methods belongs in the upper division.

Finally, I cannot resist challenging White's assumption that the better liberal arts colleges will lead the way and that other institutions must ultimately follow. This view has grown increasingly anachronistic as many institutions have become confident enough to act without waiting for Harvard or Stanford — not only lesser liberal arts colleges, but also state universities and community colleges. Private foundations have traditionally supported private colleges. But even if this pattern continues, foundations can help private and public institutions learn from each other.

To conclude, I have not criticized White because he ignores liberal education. In fact, he is deeply concerned with strengthening it. I have tried to show that, if applied narrowly, the general view of education and the Particular Program for the Sloan Foundation outlined by White will make it harder than it already is for liberal arts colleges to inculcate intellectual and moral vision.

RESPONSE 3

James L. Adams

Associate Dean of Engineering for Academic Affairs
Stanford University

Mr. White's essay left me with a combination of elation and fatigue. Elation because to be an engineer is to pay a professional and personal price for the surprisingly low overall technological sophistication in our society. Those who specialize in technology are impressive indeed in their abilities. However, a depressingly large percentage of our population seems to have very little appreciation for the capabilities and limitations of technology and to be extraordinarily reluctant to deal with quantitative and scientific thinking. The professional price results from our having reached a state where many major constraints on our technology are political, rather than the results of limitations in capability. Without an informed electorate, or at least informed leaders, such constraints can hardly be consistent with the best usage of our technological ability. The personal price results from those of us who apply science and engineering to technological problems having learned to live in an intellectual closet. We can enjoy sharing the details of our work with our colleagues. However, we have found that those details have approximately the same social appeal as leprosy. We have come to suspect that any social gathering, no matter how impressive the credentials, is likely to be liberally laced with individuals who identify science with some long-ago high school chemistry course, mathematics with the addition, subtraction, multiplication, and division of positive whole numbers, and technology with radioactive waste. Our lives would be fuller if we could parade the sophistication of our wares in public.

The essay left me fatigued because of the magnitude of the task of attaining an appreciable increase in technological literacy. I see signs of a definite upsurge in public interest in science. A glance at a bookstore or a television schedule confirms this. Many excellent popular works on science have become available in the past few years, but science is not technology. It is the source of much technological understanding and many technological developments. However, science is primarily seeking an understanding of nature, and technology is attempting to provide systems, goods, and

services of value to people. Science is seeking truth. Technology appreciates truth, but in its absence is expected to get on with the job. I also see signs of an increase in mathematical literacy in our society because of the proliferation of computers and because of positive changes in the stereotyping of the mathematical ability of women, but mathematics is not technology. It is essential to technology, and is probably the most powerful means of abstracting reality in technological pursuits. However, should mathematics not solve the problem, the technologist is obliged to solve it in some other way.

There are signs of the beginnings of a movement to increase technological literacy. Advocates have emerged. However, influential efforts such as the TV series "Connections" and "Cosmos" continue to tell us of the accomplishments and importance of technology, but not of the nature of the process that brought us plows, stirrups, gunpowder, clocks, looms, and spacecraft. They tell us of the successes, but not the heartbreaks and the failures. The press makes us aware of the importance of failures through its coverage of the DC-10, Three Mile Island, and the Loval Canal, but it does not enlighten us on the difficulties of eliminating failures and mistakes and predicting the ramifications of a major technological development.

Within the educational system, the Sloan Foundation has sponsored meetings, a few projects, and accumulated some thoughts. CUTHA (The Council for the Understanding of Technology in Human Affairs) has emerged, coordinated a successful conference at M.I.T., and is soon to sponsor another at Chatham College.* Various faculty members in a few schools have put together some interesting courses and programs and a few media people have nibbled at the area. However, the impacts have been local.

I certainly agree with White's message that a major change in the treatment of technology in the traditional liberal education should occur. Supposedly, the college-level liberal education affects the leadership of our society and influences educational policy at all levels. Certainly technology is, and always has been, a part of the human experience. The finding of a nearby tool helps the anthropologist decide whether primitive primate remains should be classified as human. Homer gloats over man-made objects. We augmented our muscles during the industrial revolution and are now augmenting our minds through the application of electronics. Technology is as unique and human a characteristic as language and to ignore it in an education that calls itself liberal is ridiculous. Yet, ignore it we often do. Liberal education is the turf of the humanists, the social scientists, and to

*The conference at Chatham College took place in June 1981.— Ed.

a lesser extent, the physical scientists and mathematicians. The faculty involved in the endeavor do not generally invest much of their time in attempting to understand the nature of technology and their course offerings and teaching materials reflect this. Those in academic disciplines traditionally associated with technology spend their energies furthering their own discipline and teaching those who will be practitioners rather than participating in general education. The little interaction that occurs is more often oriented toward examining the effects of technology rather than the process. However, although I agree with White that a major change should occur, I do not see it on the horizon as clearly as he does.

I believe that there are two large gaps which must be filled before the change will occur. First of all, the leaders of what I will call the liberal education establishment must become involved in the cause, both at the policy and the working level. Second, the proper resources must be compiled and made available to the educational system. Let me make a few comments on each of these in turn. Academia has an institutional and personal caste system. Even though energy, creativity, ideas, and excellent people are available at all levels of this system, change occurs most efficiently if it occurs first among the most eminent faculty and administrators in the most prestigious schools. An example is the present move toward increasing the structure in liberal education. The initial words and studies came from a relatively few highly respected institutions (notably Harvard) and were carried by people with high status in their disciplines and with a stated allegiance toward liberal education. For change to occur in the opposite direction is to swim upstream. From what I have seen to date, much of the activity having to do with increasing technological literacy has taken place in the technical schools. Meetings and presentations have been shy of those educators who extol the virtues of a liberal education in the halls of Congress and on the pages of *Time*. Similarly, faculty members of outstanding stature from prestigious liberal arts colleges who are actually willing and able to teach such subject matter have been few and far between.

The last thing in the world I intend to do by these somewhat elitist remarks is to criticize the efforts that have occurred so far. However, in order to affect a national change in academic direction, it is necessary to enlist the maximum available talent and influence. Harvard leads more easily than it follows. Although there is a logical argument that younger faculty should be better suited to new and non-traditional activities because of considerations of energy, less inertia, and high ideals, history indicates that not only do such efforts initiated by junior faculty often fail, but they often take their instigators with them. It is also known that change is sought both by people who have excelled at what they have done and are pushing

in new directions and by those who have not done so well. The credibility and talents of respected senior faculty are needed here.

Many of the efforts which are now occurring seem to be foci for volunteers. In my opinion, the Sloan Foundation must go beyond this and actively recruit. Such recruitment takes exhortation and education as well as financial support. Exhortation because the type of participant needed is busy and leading a satisfying life. The main motivations to participate are the importance of the activity, the intellectual challenge, and the stimulus of new colleagues. Presumably the effort to increase technological literacy has these three characteristics. This fact must be advertised.

Education because there is much technological illiteracy in the elite of liberal education. It is, unfortunately, not the unusual humanist who has severe math anxiety. I am continually bemused by how easily many of my colleagues in the humanities and social sciences seem to be able to partition technology away from the more "humane" characteristics of humanity and then, effortlessly, divide it into acceptable and unacceptable portions. They have no trouble writing a piece damning technology and then climbing on an airplane to fly to a meeting to present it. They drive their European car to my house, dressed in the latest casual and tasteful wash-and-wear clothes, listen to fine tapes on my stereo at a time of night when the fire would have long gone out in their ancestor's cave, and tell me how technology erodes human values. They seem to be immune to a realization that humanity and technology, the good news and the bad, are part of the same wonderful package.

This education requires direct exposure to technology. Faculty with traditional liberal arts backgrounds must be given an opportunity to talk with informed and stimulating specialists from a wide variety of areas of technology and they must be given an opportunity to witness, if not involve themselves in, the process in action. I teach a course which is a technological show-and-tell for students. A higher level activity of similar nature needs to be available for interested stars of liberal education. Sabbatical and study opportunities in industry need to be coordinated. In addition, these people must be given access to conventional scholarly materials (studies, readings, books, cases, perhaps audio-visual material and resource people) in the area. This material is presently in regrettably short supply. Lack of this material is the second major gap I see preventing a national move toward technological literacy.

Unfortunately, technology is not as completely represented within colleges and universities as are the liberal arts. Those in universities who specialize in disciplines particularly pertinent to technology concentrate on intellectual tools which have great future potential, are difficult to learn by

experience, and which are compatible with the academic system. Their research tends to be abstract, strongly based on mathematics and science, and intellectually tidy. However, technology is much more than this, and a large part of the remainder is not consistent with traditional education. Much of the intellectual content of technology is specific to a particular industry or type of product. Much of it is empirical. Technology must operate in the absence of theory as well as in its presence. Solid state physics produced the transistor. However, the steam engine produced thermodynamics. Technology involves risk and uncertainty, organizational pressures, and judgments based on aesthetic sensitivity. It involves great drama and passion and extreme boredom. It is a rich segment of human experience and much of this richness is absent from the halls of academe.

If we are to seriously attempt to improve technological literacy, we must make a serious effort to better capture the essense of this technological process in a format which can be used in the schools and universities. This is not a simple task. Due to the nature of humans and of the legal and economic process, technology tends to be both deeply draped with jargon and whitewashed. Society has unwittingly turned technological specialists into a quasi-priesthood. Once a priesthood forms, it becomes more difficult to convey its secrets to the masses. The technological process must be translated into terms which are consistent with the experience of the lay person. As to whitewashing, successes and abilities tend to be given much more publicity than failures and inabilities. Since the dawn of the human race, people have made mistakes and things have broken. There is precious little discussion of this in the literature. We hear about the outcomes (the Edsel, the Tacoma Narrows Bridge, the shuttle tiles) but not the details of the procedures which allowed them. We hear little of products which are never produced or tests which result in failure. We know little of the long process of development, or debugging, which accompanies any complex technological development.

Like most people who have been involved in highly visible technological undertakings, I have been often bemused by the lack of similarities between the process as it occurred and as it was presented to the world. I was employed at the Jet Propulsion Laboratory in the early 1960's during the successful birth of interplanetary spacecraft. We were a most competent and highly motivated organization. However, we were nowhere near as good as we were thought to be when our product was successful, nor as bad when our product failed. Despite the fact that we were widely heralded as young scientists, a surprisingly large number of us were bald and much of what we did involved a high degree of arguing with vendors and worrying about things we could never know. Although the newspapers might

publish a photograph of the launch and an article describing the spacecraft, its intended mission, and the loss of radio contact, they would not illuminate the readers on the process an organization goes through when it has spent years designing, building, and testing a beautiful and complex electromechanical system, had the first one fail, and not gleaned the foggiest notion as to why.

If we are to have the type of technological literacy which will enable our society to more sensitively allocate resources, regulate outcomes, and handle risk and liability, a large amount of dispassionate study of the technological process must be done in such a way that the end material will be compatible with the educational process. This study must avoid either advocacy or attack. It must be done within a format allowing peer-review, since it is difficult for individuals to retain their bearings when exploring jungles of this magnitude. It must result in a better ability to define and describe the technological process and must divide the process into subunits compatible with scholarly investigation. However, what better activity for academia? Here is a large complex area of human intellectual activity which functions and is replete with specialized practitioners and critical social impact and, somehow, it is neither well understood by the society in general nor is it being studied by non-biased social scientists and humanists. What better opportunity for publishers and producers? Here is a source not only of academic material, but also stories of achievement and failure replete with human drama. What better project for the Sloan Foundation than to catalyze this effort?

In summary, let me say that my best wishes are with White's essay. I see encouraging signs of national concern with the technological literacy level in the United States and some people within the educational system beginning to move. However, I do not yet see a major change in the philosophy of liberal education on the horizon. Before this can happen, I believe that the leadership of liberal education must take up this cause and become involved in the nuts and bolts of implementing it. In order for the change to be implemented, technology must be much better described in a form usable by educational institutions. Both of these are achievable with the proper leadership and resources. The timing is right and the illiteracy is appalling.

RESPONSE 4

George A. Drake | *President*
Grinnell College

While agreeing with much of what Stephen White says in "The New Liberal Arts," I shall begin by taking issue with his title. What purports to be new in Mr. White's presentation of the liberal arts is the admonition that applied mathematics and analytic thought *must* be incorporated in any authentic presentation of the liberal arts. As a matter of fact, there is nothing new about this notion and White, despite his choice of title, finally seems to recognize this in his text.

We have inherited our idea of the liberal arts from the Middle Ages. The medieval university curriculum, by the thirteenth century, had been standardized into seven disciplines. The *trivium,* or basic studies, consisted of grammer, rhetoric, and logic: the tools for communication and clear thought. Once these studies had been mastered, students proceeded to the *quadrivium:* arithmetic, geometry, astronomy, and music. These subjects revealed the order and proportion of nature through numerical understanding. The importance of applied mathematics, obvious in arithmetic, geometry, and astronomy, also underlay the inclusion of music in the canon of studies; for analysis of music demonstrates conclusively, to the medieval mind at least, that number underlies all relationships. Harmony, or pleasing sound, is the result of proper numerical relationships among the vibrations which produce sound. The knowledge that orderly numerical relationships are the basis for beautiful music was, to the medieval mind, a most powerful demonstration of the unity of creation—a unity which best could be understood through the study of numbers in arithmetic, geometry, astronomy, and music.

Just as there is a direct line from the medieval to the modern university, so the provenance of modern liberal arts is to be traced to medieval formulations; and, as we have seen, the mode of thought and application which characterized those studies was the mathematical. Thus, the idea that applied mathematics should assume an important place in the liberal arts hardly can be called "new" as White suggests. Rather, it is a revival of the traditional canon.

It is beyond dispute that American higher education must reassert this tradition and White's paper forcefully reminds us of this necessity. His challenge is most timely, as American higher education slides with mindless and unseemly haste into vocationalism. We are in jeopardy of giving way to the shallower dimensions of pragmatism; those which insist on the practical applicability of all studies, while ignoring the profound impact of an education which concentrates on teaching broad analytic skills, the arts of communication, and knowledge of the great traditions of human thought and creativity. It is gratifying to find such a persuasive ally of liberal learning in Stephen White and the Sloan Foundation.

White emphasizes the importance of analytic thought to a liberal education, focusing particularly on quantitative skills. Everyone would agree that there is no liberal education without analytic thought, but I would argue that analysis is as important to non-quantitative as to quantitative subjects. For example, this semester I am teaching a humanities course and most of the classes are devoted to discussions which challenge students to read accurately and to think critically and analytically. The spirit of the liberal arts is to use its subject matter as raw material for thought and communication as well as for its intrinsic value.

Stephen White ventures the opinion that mathematics and natural science are not mainstays of most liberal arts colleges. In my opinion, he is wrong. Almost all good colleges have strong science and mathematics programs, in many cases superior to those in the humanities or social sciences. There is nothing inherently antithetic to science and mathematics in the liberal arts college save the financial restraints which impinge on facilities and staff size. At Grinnell, we find that students frequently come to us better prepared to do mathematics and science than to grasp the nuances of the humanities or to write literate papers. In fact, I would argue that, contrary to White's assertion, the teaching of science and mathematics are particular strengths of the liberal arts college. This opinion does not negate, however, his assertion that numerate literacy should pervade the curriculum so that all students will be reached. Strong as are the natural sciences and mathematics in a good liberal arts college, usually they remain the preserve of a minority; and this is a mistake. Liberal education, by definition, incorporates quantitative understanding, which means that all who experience it should become mathematically literate.

White also calls for a new emphasis on technological education in the liberal arts. I am less sanguine about this possibility. While applied mathematics and analytic thought are integral to liberal education, technological studies are not. Engineering studies, as he recognizes, scarcely are to be found in liberal arts colleges and there is little hope that they will be well

received in the future — nor do I believe that they should be. Engineering is a complex and expensive discipline which could deflect colleges from traditional liberal studies while straining their resources to a point where what these colleges do best would be undermined. The liberal arts can encompass applied mathematics and analytic thought with fidelity to their purpose. They cannot mount fully fledged technological studies with equal integrity. The best that one could expect is that more courses which treat of the nature and impact of technology will be developed.

Stephen White is concerned, and with justice, about strategies for change. Generally, faculty recognize the importance of mathematics and analytic thought to a sound liberal education, but they resist the implications of total commitment to these studies, especially in the case of applied mathematics. For instance, use of the computer and statistical methods still is resisted by many humanists and some social scientists. We must take concrete steps to overcome this aversion, since, if quantitative studies are to assume their rightful place among the liberal arts, they must be entertained by virtually all faculty and adopted by more than a few outside of the natural sciences.

Faculty development will be the critical element in bringing about the "new liberal arts." As White says, faculties must be "remodeled," and almost certainly prior to significant curricular change. The task won't be as daunting as some imagine, at least in the colleges with which I am acquainted.

For example, Grinnell College might extrapolate a faculty development model from its long experience with the teaching of literary skills. For 10 years we have offered a required Freshman Tutorial which emphasizes writing skills. Five or more papers are written by each student and classes are limited to 12 so that the professor can give individual attention to each person's writing. Since over 30 sections of the course are offered each fall, staff must be drawn from a wide range of departments, emphatically putting into practice the theory that all liberal arts faculty should be responsible for teaching students to write. To prepare faculty for this difficult task, we ask each tutorial teacher to take a summer Writing Seminar (at least three sections offered on campus each summer); and each time one teaches a tutorial, one must enroll in another Writing Seminar. The program of Writing Seminars is expensive to maintain, but in a college which places a high premium on writing, the expense is warranted.

For several years we have speculated about expanding the one-semester Freshman Tutorial requirement into an additional semester which would feature quantitative literacy. Such an expansion would require even more attention to faculty development, primarily in the form of summer faculty seminars in applied mathematics, computing, and statistics. This

undertaking probably would be more costly than the Writing Seminars, because most faculty are less well prepared to teach quantitative material than they are to teach writing skills.

I have cited this example to illustrate how one college might institute an applied mathematics requirement through a fairly natural process of change. It, however, would be expensive and this is where the Sloan Foundation could be most helpful. A few colleges could sustain the cost of faculty development if they were convinced of the importance of generalizing quantitative learning, but the majority simply could not afford the combination of released faculty time, consultants, summer stipends, and salaries for the teachers of summer seminars, which well planned curricular innovation of this magnitude would require. Perhaps not all of the preparatory steps outlined above would be undertaken by each college, but any hope of success would require at least some of these steps and perhaps others.

Our experience with the lasting impact of foundation grants to help with the cost of effective curricular planning and faculty development has been good, and the college almost always has found the means to assume costs which have continued beyond the granting period. Probably the key to the developments which Stephen White calls for will be the willingness of Sloan and possibly other foundations to underwrite part of the cost of producing fresh and well conceived ideas and developing faculty to implement them.

Liberal education, which for centuries was the only form of higher education in America, now is in danger of obliteration as technical and vocational studies expand to meet the demands of the marketplace. However, the liberal arts are as necessary now as they have been at any time in our history and it is in part through a return to the traditional importance of quantitative studies that they can hope to recapture lost allegiance.

RESPONSE 5

Dick Netzer

Dean, Graduate School of Public Administration
New York University

Not surprisingly, my perspective is from inside, or at least partly inside. Although I've had some direct responsibility for only two years of my 20 in the academy (when I was chairman of the Arts and Science Economics Department in the late 1960's), I've been a very much concerned consumer of the products of undergraduate education for all 20 years and, because this is a university in which deans participate collectively in academic policy determination for the institution, I've also been continuously involved to some extent in the nature of undergraduate education at NYU for the past decade. My insider's perspective makes me concerned about the obstacles to implementation of White's ideas.

He rightly notes that curricular change is especially difficult now, in the face of contraction of that massive enterprise, close-to-universal undergraduate education. But I think there is another, even more serious problem, one that he does not mention. His proposal amounts to adding to the curriculum exposure — presumably and optimistically for a large proportion of all undergraduates — to yet another mode of thought, albeit a very important one. Now, one can correctly argue that in four years there is plenty of time for exposure to any number of modes of thought. However, this is true *only* if we contemplate something that is wildly impractical — substantial de-emphasis, even abandonment, of the concentration and/or pre-professional component of undergraduate education. In practice, four years are *not* available for a liberal education, but two years or less.

And undergraduate faculties are full of people who naturally push the claims of their special modes of thought: "a civilized college graduate *must* have been exposed to (the history and literature of Western civilization) (non-Western cultures) (foreign languages) (philosophy) (fine arts) (behavioral sciences), etc., etc.," in addition to science and math. Thus, the current undergraduate curricular reform efforts, of which Harvard's is a prime example, tend to be uneasy political compromises under which all undergraduates are required to have a light exposure to a long list of

modes of thought, with the lightest exposure (as measured by the exposure necessary to provide a decent level of familiarity) to those modes of thought most uncongenial or most frightening to large numbers of students.

I believe that, to cope with this situation of virtually limitless claims on a very limited resource, the student's time, we need some general rule for selectivity. Despite their conservatism and obvious self-interest, faculties can be persuaded over time by rational argument; they will not be persuaded by the assertion that "my field is more important (in some undefined sense) than yours." I have such a rule: the Rule of Irretrievable Loss. The rule applies to *all* stages in the educational process, from grade school through professional school. The rule is, simply, that students should be taught, on a compulsory or universal basis, *only* those things that large proportions of them will never learn unless exposed to the material at the stage in the educational process in question, and which it is important that most people passing through that stage do learn.

Irretrievable loss is a function of: (1) educational production technology — some things are extraordinarily difficult to learn except through formal schooling and some things are very much more easily handled at one stage of schooling than at others; and (2) the likely post-schooling-stage environment of large proportions of students — will they be living and working in circumstances that do not naturally entice or compel them to learn the subject matter or skills in question? Clearly, the rule has aspects of the ideal: in practice, each successive stage has to pay some attention to remedying the failures of the earlier stages. But it is not hard to see what the ideal arrangements might be.

Let me start with some obvious examples that do not deal directly with the topic, undergraduate liberal education. By now, we all agree that it is essential that everyone emerging from a graduate management program have reasonable familiarity with microeconomic tools. I think we also agree that this subject is not easily self-taught on an informal basis and that, for various reasons, it is unreasonable to expect any students other than economics concentrators, to learn to use microeconomic tools at the undergraduate stage. Under my rule, this means that microeconomics *must* be part of the core curriculum in graduate management programs (in contrast to about two-thirds of the core curriculum elements specified in the National Association of Schools of Public Affairs and Administration standards; those core curriculum elements can be self-taught later on or more economically learned at an earlier stage).

Another example is writing English prose. History offers plenty of cases of entirely self-taught masters of English prose, but the numbers may

be several hundred among the 400-500 million English-speakers who have lived during this century. Most people don't learn to write decently unless taught. Clearly, that teaching is best done relatively early, with subsequent reinforcement. Remediation at the college level is exceedingly expensive (albeit necessary) and only partly successful; remediation at the graduate school level is simply unworkable — the irretrievable loss has already occurred, and the vile writing will cripple the student and curse the rest of us for years to come.

So what does the rule tell us, or rather me, about undergraduate liberal education? My surmise — and I haven't really thought this through fully — is that irretrievable loss will occur if the following are not included in a liberal undergraduate education (in addition to remedial expository writing): the understanding that the world was not created this morning, conveyed through a sense of history and Western civilization generally; understanding of the scientific mode of thinking; mathematical skills; and, now, the computer as Stephen White puts it. *Everything else* is, to my way of thinking, optional, not an irretrievable loss if deferred to post-school self-learning, graduate or professional school (or never learned at all), or should be done much earlier (e.g., it's a damn outrage that anyone should go through secondary school without knowing the fundamentals of American government, easily taught at that level).

If my view were accepted, there would be no trouble selling White's ideas in the colleges. No doubt few would agree with me at first reading. But I think the rule is worth pushing.

RESPONSE 6

Jacques Barzun | *University Professor Emeritus*
Columbia University

1. The request to write this memorandum and the paper by Mr. Stephen White came during my absence from the city and thus shortened the time at my disposal for giving them proper reflection and for setting down the resulting comments. In order to meet the deadline, I have therefore adopted a form of response closer to the series of aphorisms than to the essay; it is discontinuous but (I hope) not disjointed. Anyone familiar with the subject of the Foundation's concern will be able to supply for himself the links and transitions that I lacked the time to put into words.

2. To a product of European schooling such as myself, the idea of including mathematics among the liberal arts is not new; it is simply a statement of fact. Nor does this inclusion date from the so-called scientific revolution of the seventeenth century and the influence of Descartes on the educational system. Mathematics and "music" were Plato's requirements for the training of the mind. *Mathema* was the word for *learning* and music meant everything not comprised in the science of figures and numbers, which is to say, the subject matter called in Roman times *litteras humaniores* and in the Renaissance simply "the humanities."

3. Viewed historically, the subjects of study in western civilization have, until quite recent times, always given equal weight to the products of the human mind's two main orientations, those to which Pascal gave the names *esprit de géometrie* and *esprit de finesse* (*Pensées*, Article I). The description Pascal gives of these two natural tendencies I have ever considered of the utmost importance, and the failure or neglect of teachers to make them vividly known to their students accounts for an enormous amount of misconception and wasted effort in both branches of study — the mathematical-scientific and the literary-historical.

What Pascal points out is that both types of intellectual perception work with principles, but the "geometrical" deals with simple, well-defined elements that are combined according to equally simple and defined rules. The only difficulty is to grasp the rule or element securely by becoming familiar with the definition, for these are not obvious parts of common

experience; they are abstract and seem arbitrary, hence their easy handling requires special attention and practice. But errors here lie on the surface and are quickly detected by those habituated to the mode of thought.

The subjects that must be handled according to the *esprit de finesse* differ in that they have no clearly definable elements and no set rules by which these elements combine. The parts and relations are perceived by what is sometimes called intuition; for there *are* parts and relations, but so subtle and complex and numerous that they defy the sort of analysis which is possible — and indeed necessary — in the subjects called geometrical. This difference does not mean that one set of subjects is chaos and the other well-ordered; all it means is that the elements of the geometrical, having been abstracted and simplified on purpose, are communicable in clean-cut fashion through figures and numbers. The other set of subjects is communicable in words whose variability and subtlety correspond to the material, but which thereby lack the fixity and obviousness of mathematical symbolism.

4. From this double description it is clear that no plan of higher education should exclude or give a reduced role to either of the two disciplines. For these two modes of thought and only these two deserve that stringent name, despite our modern habit of calling any specialized academic subject a discipline. Granted that every subject, large or small, has its peculiarities, jargon, and ways of handling — "tricks of the trade" — what truly disciplines the mind is the practice of the two Pascalian *esprits*. The proof of this is the unhappy split found among our modern students between those who do well only in the sciences and those who do well only in the humanities: one of the disciplines has failed to take — and this, as I understand, is the very topic of the present inquiry.

5. Before going further with the causes and the possible remedies, one remark is in order about something said in the position paper submitted to comment. It speaks in the first paragraph of "acculturation" being ensured in our day and for a long time past by what is known as "a liberal education," which is then described as serving the individual through understanding rather than the needs of society through action. I confess I do not know of any such liberal education in the present or in the last hundred years. I recognize the words as being the frequently stated ideal, the lip-service of writers of college catalogues, commencement speakers, and admissions officers of professional schools. But ever since the entry of science into the curriculum in the 1880s the normally liberal subjects have been turned into specialist subjects having little or no liberalizing effect. One need only reread Woodrow Wilson, who in 1896 was demanding that the college curriculum should "re-generalize every generation"; or William

James who a decade later was saying that unless the sciences were taught humanistically they did not educate.

The point of these and innumerable later calls to reform is the *practicality* of the basic disciplines, the scientific (which includes the mathematical) and the historical (using the word as does Margenau to denote the realm of the non-scientific). A discipline is practical in that it enables the mind to adapt itself and exert its power in any new situation of the same species. The opposite of discipline is training. Train a man to be a butcher and you cannot expect him to lay bricks or run a hotel. But with competence in mathematics and the humanities *plus* a motive for adapting them to business or engineering or government service or medical research, the disciplined mind will readily learn the particularities of the specialty to which it is drawn. That is the best argument for spending time, money, and effort on educating (or on being educated) beyond secondary school.

This conviction is not original with me, as I have shown by citing Woodrow Wilson and William James. It was also Whitehead's argument in the generation between theirs and mine. Why is it still a matter for argument? Because of two obstacles: one is the misplaced practicality of the common mind, which trusts only training and conceals under the name of education only other forms of attempted training. The college of today is a hybrid affair, in which some few teachers try to give a liberal education (though deficient in science and mathematics), while all the others train and recruit for specialties—scholarly, scientific, and nondescript. "I've gone visual," said a Radcliffe student to me not long ago. The meaning was that she had been relieved of the burden of reading any books—and naturally of taking any science or mathematics. Looked at in the light of intellect and experience, the modern college, with its elective system and the proliferating "subjects" that make it up, is a fundamentally frivolous institution.

Fortunately, it is *not* the medium of acculturation that White mistakenly (as I believe) takes it to be. We should be in worse straits than we are if it were so. Acculturation is an invisible process. All the college does is to afford a shelter for the uneven maturing of youth, while giving imperfect glimpses of various aspects of contemporary civilization, including the several branches of knowledge.

I question also in the submitted text the common belief that the monster of Change rides on our backs and causes deep troubles, which we can get rid of only by adapting to It. The changes that beset us are on the surface, daily and hourly alterations of detail; that is why they are so exasperating; they make us feel helpless and tormented like Gulliver under the shower of Lilliputian arrows. Great changes are rarely felt as such; we have deceived ourselves by the overuse of the word revolution in everything

from "wonder drugs" to automatic check-cashing. What we do suffer from, incessantly, is multiplication: the *number* of people, words, motions, encounters, sensations, desires, events. These breed the surface changes as well as oppress us directly — the mere idea, for instance, of having to apply and be put on a waiting list in order to visit one of our vast National Parks. Our individuality formerly numbered as "one" becomes a vanishing fraction as the denominator grows larger and larger.

6. This fact brings us to the computer, which looks at first like the device for creating order out of the chaos we have so systematically created. "The task of analysis threatens to become overwhelming," says White and no one can deny it. But at the same time the computer encourages and increases the multiplication. *Any new automatism works against selectivity* and the result is an indiscriminate barrage in place of a deliberate act, one having a doer and a purpose. Hence, for example, the flood of mail, which not only has crippled the postal system but defeated the mailers' purpose, since everybody now says "junk mail" and throws it out unread. That is not exactly "analysis."

On a higher plane, the computer also finds its limits when the object is, precisely, intellectual discrimination. Thus, after a hopeful and expensive trial with indexing by computer, the makers of the monumental *Dictionary of Scientific Biography* in 15 volumes had to engage scientist-indexers to do the work by hand (and mind) over a period of two years. The point here should not be mistaken: I am not attacking the computer. It is a marvel and it is now indispensable. But its very power — and this is the point — can worsen our mental and physical state if it is not used with judgment and discrimination. To take again a superficial and therefore highly irritating "change" in our condition, the computer has made it more difficult than before to straighten out trivial business errors. If your check in payment was not properly credited, there is no sympathetic and intelligent cashier to talk to for rectification, and the computer may take months to undo a simple mis-direction. The retreat of mind and of judgment before any machine is now a commonplace.

7. The bearing of all this on education is plain, and it is much graver than is implied in the position paper's proposal that "in time, students should be acquainted with the computer in some reasonably respectable fashion." If all that is done is stuff into the curriculum a required course in Computer Theory and Technique (and how will time for it be found, now that all foreign languages have been kicked out?), then we shall have the usual spectacle of some taking to the subject like ducks to water and perhaps making a career out of their talent — all to the good; others — predictably the majority — will groan, and fail, or just get by, or get a dean's

dispensation from the requirement on the grounds of invincible inability to compute. And just as we have the (quite fanciful) *dyslexia* with experts presiding over its epidemic blight, so we shall have *dysnomia*, with remedial programs costing more than the regular work and affecting *all* work with figures and numbers, including infant arithmetic.

8. The improvement of the curriculum in the desired direction — toward making every educated person familiar with figure and number so that "learning the computer" will be only the application of a discipline — that improvement must begin early, by a reform of the teaching and the textbooks used from kindergarten on. The Council for Basic Education has just issued a paper on the faults of this earliest schooling, and the same critical eye should be bent on all the later stages.

What has always plagued the teaching of mathematics is a failure of pedagogy. The "new math" was a good example of a recurrent error which I have elsewhere called "preposterism" — putting at the beginning what the well-instructed can do at the end: the cart before the horse. The Look-and-Say teaching of reading is an earlier example, unindicted for 40 years. It assumed that because practiced readers take in at a glance the outline of a word, ignoring the letter-by-letter analysis, children to whom each letter was new and strange could do the same.

Teachers of mathematics will continue to be recruited from those with an interest in the subject, but they must be trained to see and feel the difficulties of pupils for whom Pascal's "geometrical" mode of thought is not easy. Other things being equal, the more brilliant the mathematician the poorer he will be as a teacher. I can remember a calculus teacher who physically could not explain a difficult problem. He would willingly go over it step by step, slowly, to a succession of "Don't you see?" But he had no idea in his head with which to undo a misconception or verbalize the process by which one got from line 3 to line 4 in the proof. We were told he was one of the most brilliant younger members of the department.

What is needed is the spirit and skill exhibited in Sylvanus Thompson's little book, *Calculus Made Easy*, which has the liberating motto "What one fool can do, another can." The point I am making is one that cannot possibly be overstressed. To make the whole educated world numerate in the way it once was literate, we shall need teachers who are articulate and imaginative about the difficulties of their subject. There are such today, but too few — or in the wrong places. As provost of a university that had a large and distinguished department of mathematics, I presided over negotiations that led to a marked improvement in the teaching of required Freshman math: I persuaded the department to let hand-picked young instructors in engineering do the job. At once the rate of failures decreased

and soon the reputation of the course changed from "blind torture" to "tough but good." The engineers could explain; they not only had sympathy with difficulty, but could detect where it lay. These attitudes and operations are called: teaching.

9. Under proper teaching the student does not merely pass the course; he acquires a discipline, which becomes a lifelong possession if the course is followed by others suitable in contents and instruction. Thus equipped, the person primarily interested in subjects ruled by Pascalian *finesse* turns into a truly balanced intellect, conversant and at ease with the two modes in which the single human mind has exercised its powers. At the same time, a person who takes naturally to the figure-and-number mode should be likewise equipped to deal with the other kind of analysis, the intuitive, which being less obviously regulated takes much work before one even suspects that there are rules of order in it too. Both temperaments then give up the prevalent habit of hating or despising each other.

Certain by-products of such an education would be useful to our present-day culture, among them the recognition that analysis, of whatever kind, is always purposive. It does not find the absolute elements of anything, but partly makes, as well as finds, what it needs for its purpose. Therefore many analyses that seem at odds with each other are equally valid, though some may be more convenient than the rest. The further advantage of this reasoned tolerance is the awareness that various subjects require different modes of analysis. This knowledge would save much of the money and effort now spent in trying to impose numerical analysis on matters inherently resistant to it — the esthetic, the purely psychological, the historical (here taken in the sense of reliving the past). When the domain of economics, where numbers seem ready-made to explain it, fails not simply in analysis and prediction, but in its linking of terms and facts (e.g. the GNP is *not* the measure of actual production), it is clear that the modern imperialism of numbers trying to colonize all regions of experience is a mistake. It is one, however, that reinforces the argument for educating everybody who can stand it in the double discipline of geometry and finesse.

10. A footnote to this last desideratum: the "two cultures" which everybody has been deploring since C.P. Snow's Reith Lecture are an illusion. This description is true on two counts. In the first place, Snow was not thinking of the big world when he wrote the lecture. He had just finished a tour of American colleges and universities, where he frequently found an undergraduate requirement of a year of science and mathematics for all students. He thought it admirable when compared with the English college practice of "reading" in only one subject. I vainly tried to

tell him that the carrying out of the American requirement did not produce men and women who loved equally the second law of thermodynamics and the works of Dickens. He went home to preach the American gospel to the English rulers of higher education.

When the outside world latched on to his phrase to express the split between two types of professional men, Snow accepted the use of his words in this wider application. But the application is misleading. Two cultures have always divided the highbrow from the low- or no-brow, and this continues to be so. But the highbrows today no longer form one group or even two. They are divided into dozens of — not cultures, but *specialties*. Scientists admit that *within one science* they cannot freely converse with specialists in a subbranch. And on the other side, real conversation is rare even among devotees of art or literature or history or the law, because these have all become encrusted with specialism.

Now specialism will remain, for utility, and the only question is whether education — the discipline of adaptable minds — can survive the encroachments of specialism where it serves no purpose. It is obvious that no education will enable everybody to reach the levels of discourse on which modern science and mathematics, modern literary criticism and musical theory now dwell. It isn't enough to "know" the second law of thermodynamics or be able to define structuralism. What matters is to understand the ways of thought by which these dizzy heights have been reached, to possess some concrete examples, and to exercise with due caution the critical and disciplined intellect.

RESPONSE 7

Peter Caws

Professor of Philosophy
Hunter College and the Graduate School
City University of New York

Liberal education was identical with classical education, once, because what was classical belonged to the *classis*, the top class in Roman society, and the members of the *classis* were free men and required an education appropriate to that condition. It is gratifying that the tradition of liberal education can be carried on in the democratic state by a mere change of emphasis, from the adjectival form *liber* meaning "(already) free" to the verbal form *liberare* meaning "to set free." But the change signifies something deeper for us—it reminds us that, constitutional provisions notwithstanding, societies like ours are not free by fiat, but that the freedom of their members has to be won and sustained against an ever more complex accumulation of obstacles and constraints. The struggle proceeds on many fronts: in the legislature, in the courts, in industry. But one of its chief weapons is still education, and liberal education is no outmoded slogan.

The focus of attention in these essays is, I take it, on the question of what training in quantitative skills has to do with the freedom of the educated man or woman in the contemporary world. If we knew how to answer that question we would be able to adapt the practices of liberal education to the challenge of applied mathematics and the computer, perhaps with the help of the Sloan Foundation. How much "quantitative literacy" is desirable for the graduates of our liberal arts colleges? How can they be encouraged to acquire it? It may be worth staying with Latin for a little longer (it often is—we have a great fund of unsuspected knowledge, as it were "by recollection" in Plato's sense, in the classical roots of our everyday language) in order to meditate on literacy and the quantitative. The expression "quantitative literacy" seems to me perfectly acceptable and exactly descriptive, but it invites reflection on what other kinds of literacy there might be.

It is generally assumed, of course, that "literacy" means reading and writing, but if we pursue the origins of the term it just comes back to liberal education again. *Littera* means a letter of the alphabet, hence *littera-*

tus is "lettered" — sometimes in unexpected senses: *servus litteratus* meant a slave whose master's letters had been branded into his flesh as a mark of ownership. The letters might have been numbers, since as everyone knows Roman numerals *were* letters; being lettered, for an educated Roman, amounted to having at one's disposal the whole symbolic repertoire of the culture. What one might want to do with it could just as well be quantitative as qualitative. "Quantitative" and "qualitative," in their turn, were only some of the available possibilities; they happen to be the only ones to have been preserved in the language, but Latin provided for curiosity in all sorts of other respects. In addition to *quantus* for "how great" and *qualis* for "of what sort" it offered, for example, *quam* for "in what way," *quando* for "at what time," *quare* for "by what means"; we could imagine "quamitative literacy" dealing with modalities or "quaritative literacy" dealing with causes.

The point of these fantasies is not to overload the language but to stretch the reader's habitual expectations about it, so as to avoid the prejudices that the contingencies of its history have built into our usage. Why should we have allowed a gulf to open up between one kind of description of the world and another, and why do we assume that everyone can go on indefinitely with verbal elaboration, and have access in principle to the farthest reaches of the literary universe, while more than a few steps in the direction of the numerical or mathematical require special talents the lack of which can be shrugged off without embarrassment?

The language of mathematics, it is true, is not a conversational language; the book of Nature, which as Galileo used to say is written in it, may need translation before it can be read easily by people without special training (which is not the same thing as special talents). But such translation is surely possible, and the subjects dealt with will not be less quantitative for being expressed in discursive rather than formal or symbolic terms. It is important for people to be aware of the existence of formal systems and to have some idea of their power, even to have a paradigmatic acquaintance with the symbolism itself (in order to de-mystify it), but nothing more than this and a good command of English is required to grasp what is involved in the gradient of a curve, the square root of minus one, and exponential function, non-Euclidean geometry, even Hilbert space — *provided somebody is available to explain them in English.*

This last is of course the crucial point, and I will return to it. It suggests that any program for improving the quantitative literacy of students is going to have to be at least a two-stage affair. My point for the moment, however, is that quantitative understanding and the actual manipulation of quantities are not the same thing; idiot savants who can extract cube roots of twelve-digit numbers in their heads may not have much of

the former, and conversely people who have a clear grasp of how quantities vary, interact, represent themselves in events, etc., may still make elementary mistakes in the latter. One of our problems may be that too many beginners have been made to feel stupid by the unimaginative teaching of arithmetic and gone on to believe that they were essentially hopeless at mathematics.

But "mathematics" derives from a root that meant simply *learning*. And the problem under discussion requires us to go more deeply not only into what is learned, but also how and from whom it is learned. We have managed to learn the two-cultures dichotomy, which cannot be blamed on C. P. Snow (though he made it worse): where did we get it? It may be that the true culprit was Pascal. In the seventeenth century the possibility of applying mathematics to virtually everything in the universe, not just weights and measures, began to be taken seriously: Kepler, Galileo, Descartes, Newton, Leibniz represent a development of the exactitude and the ambition of mathematics as descriptive of the natural and even the social worlds. Pascal took part in this development, but became convinced that the "geometrical spirit" *(l'esprit de géometrie)*, while it could go as far as it was possible for humans to go in the rational explanation of things, necessarily missed something essential about the spiritual life of mankind, for an understanding of which the "spirit of subtlety" *(l'esprit de finesse)*, lacking in crude rationalists like Descartes, was indispensable. The opposition between an unimaginative and Procrustean mathematization of the world and a sensitive, feeling, and poetic representation of it in literature and art has been with us ever since. Naturally the opposition can be stated in different terms: as between a careful, modest and rigorous investigation of Nature on the one hand, and a self-indulgent, confused, and ignorant playing out of childhood fantasies on the other. "Books about books about books!" I once heard an eminent scientist exclaim scornfully about some of his humanistic colleagues. One cannot pretend not to understand the sentiment.

But of course all such passionate and Manichaean battle-cries are oversimplified and, what is more serious, destructive. Suppose we push the question about learning back to an earlier point in the life of the humanists or scientists in question, to a stage before the explicit contrast between qualitative and quantitative comes into play. Without appealing to Piaget in epistemology or to Kohlberg in ethics it is safe to say that early learning takes place in a social context, that the earliest propositions internalized by children belong neither to the natural sciences and mathematics on the one hand, nor to the humanities on the other, but to what would now be called the social sciences, or as the French put it the "*sciences humaines*." It would

not be a bad idea to design a curriculum that represented the main object of education as becoming human in a social sense, and showed how specializations in mathematics or in literature constitute diverging patterns of growth from the social center under the influence of various historical, psychological, and utilitarian pressures — and that furthermore they are complementary to one another in the life of society and that understanding them, and the people who practice them, is a necessary part of understanding ourselves. And this brings us back to the question of how to get the quantitative material in, for the people in the middle or those veering off in the direction of literary studies.

So far I have been viewing this problem as in part a problem of transcending an old opposition, one that has been entrenched in modern culture since the rise of science three or four hundred years ago. My first recommendation is to exploit the fact that both sides of the opposition represent human practices carried on by people like ourselves, or like the students we teach, so that a continuity between the extremes actually exists in each one of us, in the possibility we all have of becoming mathematicians on the one hand or poets on the other. The possibility we *all* have: the phobia about quantitative studies that afflicts some people is, I have suggested, an artifact of inadequate pedagogy, if not the actual inculcation of a sense of mathematical ineptness then at any rate a failure to stress the innate capacity shared by all but the brain-damaged. (The change in pedagogical practice needed to correct this shortcoming, while overwhelmingly difficult in practical terms, is not terribly interesting in theoretical ones. It is well, however, to be reminded that any theoretical proposal can come to grief over practical obstacles and very likely will.) This first recommendation amounts to a refusal to accept the dichotomy and an assertion that there exists a more fundamental set of disciplines — as seen from the point of view of the learner — than either the sciences or the humanities, namely the social sciences. The resulting curriculum would be based on introductory material in anthropology and linguistics, perhaps some sociobiology and sociology of knowledge, some history of science, designed to acquaint the student with the mode of insertion of the human into the natural world, the resources of the mind and the constraints of the environment which made it first possible and then necessary to count, to measure, to calculate. To demonstrate the Pythagorean theorem as the solution to a problem of Egyptian land-surveying, or the incommensurability of the square root of two as casting doubt on the rationality of the world, can provide a paradigmatic acquaintance with some serious — albeit elementary — geometry, arithmetic, and algebra in a non-threatening context; to study

the abacus as a primitive cash-register can open the way to understanding the computer without representing it as a bit of high technological magic.

But it is possible to approach the whole question on a more fundamental level. The process of education, acculturation or whatever, however carried on, results in the possession by the learner of what may be called a *mental structure*, that is, a functional system of relations between perceptions and ideas, ideas and words, ideas and other ideas, words and other words, ideas and acts, etc. The technical vocabulary is unimportant; the point is that an educated person (and this is how we tell that he or she is educated) is able to respond to a question, to choose between alternatives, to carry out tasks or purposes, etc., and what is involved in every case is the following or instantiation of a relation which has somehow been internalized. If we say "Othello" the response is "Shakespeare" and not "Shaw," if that is the kind of challenge it is; if we say "4^2" the response is "16" and not "17" or "25¼." The idea can easily be generalized. Elsewhere I have called the process "in-struction" to reflect the fact that mental structure is in some sense "inner" as opposed, for example, to the structure of the natural world to which its possession makes our responses more or less adequate. Some instruction is genetic, in that the relations it establishes are programmed in the DNA the instructed individual was provided with at conception; I call this kind also "endosomatic" because it represents a transmission from individual to individual (in this case also necessarily from generation to generation) *within* the body. (Most, although not all, of the relations that constitute mental structure are carried by physical connections of one sort or another in the brain, and the brain is safely in the body. I am not claiming that mind is "in the body" or indeed anywhere, and I use "mental" only to distinguish activities like playing chess or reading philosophy from physical activities like eating or climbing stairs.)

A great deal of instruction, however — indeed in civilized societies nearly all of it — is cultural or "exosomatic," in that the transmission of structure from one individual to another, from teacher to learner, from expert to novice (and also in the generalized sense from generation to generation), involves the mediation of language or other external means of communication. *Some* exosomatic instruction is what is called "learning by experience," in that the learner is not taught by anybody but finds out from observation, trial and error, etc., how the world is, but in an environment as complex as ours, all of which has to be learned in the first decade or so of life, there is really not time for much of that, and we internalize the required structures in great chunks, made ready by our predecessors in the form of books, college courses, computer programs, etc. There is a

risk in this that we may wind up believing a lot of nonsense, and of course this regularly happens, but that is not the issue at hand.

I have found it useful to discuss this question of structure and instruction quite openly with students, who should after all become self-instructing systems as soon as possible; the cultural environment is rich enough to make this feasible, and the learner can learn from people who are not actually present, most of whom may indeed already be dead. The relevance of all this to the topic of quantitative literacy is that becoming literate in this sense involves the acquisition of a different kind of structure from that required by verbal or textual literacy. Literature, philosophy, the humanities generally — and also for the most part the social sciences — are *discursive*, in the two senses of tracing out lines of thought or argument and of running hither and thither over some field of inquiry so as to build up progressively a more adequate idea of it. Mathematics and the quantitative sciences can be approached discursively too, as was suggested above, if someone can be found to translate their ideas into ordinary discourse. But in teaching them there will arise sooner or later the need to introduce *recursive* relations, whose defining characteristic is that instead of one thing's leading to another, as it were, we are constantly called upon to go back and carry out the same step again — and again, and again, and again.

Consider counting: when the child has learned the basic poem "One, two, three, four . . . twenty, thirty, forty . . . a hundred, a thousand" and so on (I call it a poem deliberately: it is something made out of memorable words for recitation) it also learns that any integer will yield the next higher integer upon the operation of adding one, and that this can be done again and again up to any arbitrarily large number. Catching on to this is a heady moment in early learning, and there must at this moment exist in thousands of children's rooms all over the world, as there once existed in mine, well-thumbed sheets of paper on which in irregular columns the colossal but exciting task of writing out all the numbers from one to one million, say, is being undertaken. Of course recursive activities are boring; at 337, perhaps, friends come to play ball and the enterprise is abandoned; it goes on from 338 to 362 in a different colored ink and a few weeks later is cleared out and thrown away. But the idea is of immense importance and needs to be caught for the purposes of future understanding, although it can be restated more perspicuously later even if lost in childhood.

Computers operate essentially by the recursive application of one operation until the instruction is given to move on to the next. The Turing machine, that idealized ultimate computer, does just one thing, over and over: it reads the tape, consults its internal state, and carries out whatever operation this combination of inputs dictates (printing, moving the tape);

it then repeats the process. While a lot of mathematical work is non-recursive in the strict sense, the *idea* of recursion is basic and can be communicated, as can the ground of its usefulness. Nature is endlessely repetitive, and its fundamental parts are essentially similar to one another within a relatively small number of types; what it does with these parts — very large numbers of them, which accounts for the surface diversity of things — is essentially additive or recursively interactive in slightly more complicated ways, and this means that its processes can be simulated by a machine of suitable capacity and patience. One of the functions of the human brain is to be such a machine, but its capacity, while great, is not optimally organized for long and repetitive tasks, its patience is limited, and its memory for large quantities of data has to be externalized (in notebooks, files, tables, etc.) and suffers from very long storage and access times. Most of the serious work is therefore done by computers in tandem with brains, the latter playing a small, but real and often indispensable, part in the process.

Why is it important that learning all this, and to some degree practicing it, should be part of the education of men and women in a free society? Obviously because the mastery of the processes of Nature (and of the recursive features of culture, such as economics and the calendar and the operation of domestic machinery — I might add parenthetically that the system consisting of car and driver is remarkably Turing-like and can be used to make the idea of recursion vivid) is a condition of their freedom. If we do not have some basic understanding of the processes which make our freedom possible then we enjoy it, in a way, under false pretenses. Everyone admits this in the case of politics, and would agree that a person ignorant of the principles of his or her own government is not liberally educated. And exactly the same case can be made for quantitative literacy if it is admitted that freedom to do what we freely choose to do has as an essential component the availability of the resources and information of mathematics and the exact sciences. The other side of the same coin is that not being quantitatively literate puts people at the mercy of others who are, as well as of those who whether literate in this sense or not have power to manipulate quantities. Political economy is full of examples of this, and not only in the past.

The question of strategy remains, and of institutional resources. As must by now be clear the basis of strategy as I see it is self-understanding in a social context: not telling students that we are going to train them in applied mathematics whether they like it or not, but bringing them to appreciate how mathematics is already applied in a world of which they are already a part. Just to come to see the pervasive presence and tremendous power of recursive procedures, the reiterated application of simple

principles up to very great levels of complexity, is a long step towards quantitative literacy. And other general concepts like recursion can also be identified and taught. It is not so much, in my view, "the ability to cast *one's* thoughts in a form that makes possible mathematical manipulation" (to quote Stephen White and add a bit of emphasis) that is called for — since one may not, for the moment, have any thoughts with respect to which this would be an interesting or rewarding activity — as the ability to see what *sort* of human thoughts and activities lend themselves to being cast in this form, to see how they were in fact cast in it and why this was, and is, important for all of us.

The required resources are faculty members who can talk this language without intimidating students in whom the cultural prejudices discussed earlier have been allowed to take root. There are not, perhaps, too many of them at the moment. But my own experience with interdisciplinary general education courses suggests that it is a language accessible to students of average abilities, and if one member of a faculty can talk effectively in this mode to students, it should certainly be possible to do so for other faculty members as well. Call it recycling, and build in a multiplier effect. That is the sort of thing foundations ought to be good at.

RESPONSE 8

Donald L. Kreider

Chairman
Department of
Mathematics
Dartmouth College

The view of mathematics held by society at any given time is dependent on its short-range goals and the contribution that society believes mathematics can make toward achieving those goals. During the past half century, we have seen the public's stance shift from its historical oblivious position toward mathematics to one of nearly unquestioned admiration and support and then, more recently, to a somewhat cynical reaction against attempts to reform mathematics teaching and against perceived excesses of technology with which mathematics is thought to be linked.

In the broader sweep of history, however, mathematics has always claimed a cornerstone position in any definition of the liberal arts. A compelling reason for this is stated in Stephen White's paper, "The New Liberal Arts." He maintains, there, that analytical thinking is one of the two means developed by mankind for organizing and comprehending the data and ideas in which we are immersed. And one of the chief roles of mathematics is, and always has been, to provide a language and a modus operandi for the analytical process. Periods of negative sentiment toward the place of mathematics in the liberal arts curriculum must accordingly be viewed as aberrations.

There is evidence that we are emerging from the most recent such educational recession. This is fortunate in view of the need for a citizenry that is prepared to work and contribute in an increasingly technical world. The high priority assigned by our serious industrial competitors — the Soviet Union, West Germany, Japan — to the nearly universal education in science and mathematics of their citizens is just one reason for quickening our recovery.

But even apart from such pragmatic reasons for increasing our support for a broader, more quantitative view of liberal arts education, there is also a compelling social reason for such reform. Society never has, in its periods of aversion to analytical reasoning, been able to stay the growth of new ideas in mathematics or science. Rather, at such times the more unfor-

tunate effect has been to render these disciplines more elite, denying to a large portion of its citizens the ability to participate in lives and careers that require analytical skills. In the past, the slow pace of technological development may have allowed society the luxury of choice—social equity being the main victim of a lethargic educational system based on a narrow view of the liberal arts. Today that luxury has been swept away by the competitive and complex technological world which must be reckoned with—this time the victim of lethargy will be our own preeminence.

Mathematics has been part of human culture since men began pondering the physical world, seeking to understand its whims and to turn them to his own purposes. Most early civilizations relied on applications of mathematics to further their agricultural or commercial aims and it was natural that mathematics itself would become an object of attention. The classical Greek study of logic and the axiomatic method gave form to mathematics as an independent discipline, and it has progressed from that point onward as a philosophical methodology as well as an applied science. Mathematics had become a liberal art.

Inevitable as the study of mathematics had become, it was the birth of science in the seventeenth century that brought one of the grandest alliances of mathematics. Stephen White referred to C. P. Snow's allusion to "two cultures" — scientific and humanistic. We can follow Eliade's view (Mircea Eliade, *The Myth of the Eternal Return*) that a culture is defined by its myths and rituals — its myths being the tacit assumptions, at a sub-linguistic level, that predispose members of the culture to structure their view of the world in some particular way, and its rituals being the means of perpetuating the myths from one generation to the next. Usually the rituals are linguistic, artistic, musical, dramatic, etc.

In such terms, a scientific culture might be characterized in terms of its *myths*: belief in "cause and effect" and "order in nature." For without such faith that events of today are correlated with those of tomorrow, science as we know it would be impossible. The *rituals* of science would then be the linguistic means for perpetuating the myths, for unfolding them and exploring the truths that are inherent in basic assumptions about nature. Calculus, for example, would be a ritual of science, it being one of the early mechanisms devised for exploring the consequences of physical "laws." As is exemplified by the growth of Newtonian mechanics, a particular world view develops as the consequences of a given set of physical laws (assumptions) are explored. Different world views result, of course, from different assumptions. But the common feature in a scientific culture is the faith that the use of mathematics to model and predict events in the physical world is a fruitful way to approach truth about nature.

C. P. Snow's argument would seem to be that the humanistic culture, if it is indeed appropriate to describe it thus, is distinct to the extent that it fails to accept the analytical methodology of the scientific culture. That is not in itself inappropriate. But to deny its equal place in a liberal arts curriculum is absurd and foolhardy.

The Role of Mathematics

It now becomes possible to understand how difficult it is to fashion an effective mathematics education. Among its many roles, mathematics serves people broadly in elementary problem solving (arithmetic, "consumer mathematics," algebra), as a language (ritual) for science, as a norm for rigorous argument, and as an independent discipline, evolving according to its own internal needs but also according to needs of applications and sciences not yet conceived. Not everyone needs to proceed into all of these areas, yet the American view of education is that doors should be left open for every student as long as possible. It becomes a nearly impossible task to keep these different roles in proper balance as mathematics education proceeds. Small wonder that some mistakes have been made. Consider the various criticisms of mathematics teaching:

- not enough basics
- too much drill
- too little conceptual framework
- too few applications
- not enough "learning to think"
- too much rigor

The evident tension between the teaching of applications and techniques on one hand and appreciation of mathematics for its logical coherence on the other is very real. Erring in either direction is unfortunate and unacceptable. Today most college mathematics courses are devoid of realistic applications. As a result, mathematics appears to many students as sterile and dull. But attempts to include applications at the expense of theory, that is, to ignore mathematical structure and "mode of thought," is just as unsatisfactory, leading to "cookbook" methods for solving special problems. In such a setting students are left with a feeling of powerlessness when confronted with problems that do not fit the learned paradigms. Students come to feel that mathematics is a tricky subject, with unsolvable problems lurking around every corner.

Thus the problem always has been, and still is, to bring theory and applications into appropriate balance. Power in problem solving must grow out of facility with both.

At first blush, it might seem that to inject the computer into this milieu would hopelessly complicate the task of mathematics education. But, oddly enough, the computer has had exactly the opposite effect. It is becoming more and more clear that the computer, far from merely facilitating routine computation and data handling, is permitting a marriage of pragmatic skills and theoretical structure that has eluded teachers for generations. Even some of the most obvious uses of the computer succeed in changing the conceptual basis of elementary mathematics in a fundamental way.

As a simple example, the definite integral has many applications in mathematics, physics, economics and other sciences, deriving from its definition as a limit of approximating sums. The process of evaluating definite integrals, however, has traditionally emphasized the relation between derivatives and integrals as expressed in the Fundamental Theorem of Calculus. This elegant bit of theory is well known to every student of calculus, leading to weeks of practice in techniques of integration. The pedagogical difficulty arises from the fact that students lose sight of the simplicity of the original concept of definite integral, identifying it instead with the *process* for evaluating integrals. For the randomly selected application in which the resulting integral does not yield to any of the techniques learned, the student tends to classify the problem as "unsolvable."

In this setting, the computer restores balance. Any of the well-known methods of numerical integration can be implemented easily and efficiently on a computer, restoring students' confidence that any definite integral can be handled. A student is once again able to conceptualize a definite integral as a *real number* whose existence is independent of the student's own particular experience. The computer program becomes the "solution" to the problem; that is, it describes an algorithm for approximating the real number to any desired degree of accuracy.

The above example is typical of many involving the computer. In most cases, the computer serves to implement algorithms that are more general and more transparently related to the concept involved. As another well-known example, the bisection method provides a universal algorithm for solving an equation $f(x) = 0$ on an interval $a < x < b$ in which a continuous function $f(x)$ changes sign. In principal, it can be used to solve virtually any equation that arises. In practice, it is not a convenient algorithm for pencil and paper computation. When implemented on the computer, however, it acquires a simple elegance that enables the student to focus attention on the real number that is the solution of $f(x) = 0$ rather than on specialized algebraic processes for renaming that number in a form more accessible to manual computation. Students who never acquire the algebraic facility to

handle even simple equations can both understand and solve equations using the computer.

The challenge in bringing the computer into elementary mathematics courses is in preserving the best of formal mathematics while exploiting the computer's power. The most successful examples are ones in which mathematical theory and computation algorithms compliment each other. For example, evaluating the definite integral $\int_0^{\pi} \cos(x^2)dx$ requires significant preprocessing using a change of variables and integration by parts before numerical methods can be effectively used. In another example, generating empirical evidence for the Central Limit Theorem using the computer and Monte Carlo techniques helps students in probability theory to appreciate the power of mathematics embodied in the general theorem. In these examples and many others, students have been traditionally resistant to proving theorems for which they are unable to generate a single relevant example. The computer changes this state of affairs in a dramatic way.

Implementing Change

Rarely has the need been so compelling, the call so insistent, and the means so readily available for initiating a substantial change of direction in liberal arts education. The need has been emphasized in the preceding pages and in Stephen White's article. The call is from students themselves, who are flocking in ever increasing numbers into beginning mathematics and computing courses, as well as from panels such as the National Research Council's Panel on Training in Applied Mathematics, chaired by Peter Hilton, and the Mathematical Association's Committee on the Undergraduate Program, Panel on the Mathematical Sciences, chaired by Alan Tucker. Both groups urge more realistic applications in undergraduate mathematics courses, greater emphasis on the mathematical modeling process, and more explicit attention to the computer throughout the mathematics curriculum.

The means to achieving the above, without sacrificing the broader theoretical role of mathematics, is the computer. It both enriches the existing concepts from beginning mathematics courses and also raises new questions about the nature of algorithms and computations that need mathematical treatment.

At Dartmouth, the mathematics department's program has for nearly a quarter of a century reached large numbers of students through its courses in finite mathematics, elementary computing, and mathematical modeling in the social sciences. Some 85-90 percent of all Dartmouth students take at least one course in mathematics, even though there is no

institutional requirement that they do so. The presence of computing on the campus is pervasive, entering integrally into some 180 courses, half of them outside the sciences.

Nevertheless, it has recently been found necessary to take additional steps in the revision of our program. During the past year, additional computing examples and elementary computing science ideas have found their way into the beginning calculus sequence. The modeling process is receiving more explicit attention. And the linear algebra content of these courses is being made more concrete and computational. In addition, new courses at the sophomore level in applied linear algebra and dynamic systems are being introduced, and existing service courses in applied mathematics have been substantially revised in consultation with the physics and engineering departments.

As was the case 25 years ago, these changes will not be complete until new materials are developed to replace or supplement existing textbooks. Certainly the stability of new ideas and the possibility of transplanting them to other institutions will not be assured until such new materials are produced. External support for such development will need to be found. There is, in addition, the need to develop a laboratory for analytical skills that will serve mathematics and other departments at Dartmouth. Again, support will need to be found to initiate and try out various ideas about how this should be done.

There is one additional area that needs attention as a result of the very success and popularity of computer science itself. The introductory computing course for non-science students is no longer serving its original goal. Many students sense that a more serious course would be more valuable, and they have been turning in increasing numbers to the beginning course in the sequence designed for computer science students, a course not intended to raise important questions about the nature and role of computing in society. Thinking has thus begun about a new two-course integrated sequence in finite mathematics and computing that will open up to all students the more serious treatment of the analytical thought and modeling process, supported by the computer, that students are demanding.

Need for Support

All of the above changes require time, experimentation, and production of new materials. Given the financial constraints today on higher education, it is not reasonable to expect the resources for carrying out such change to be found within the institutions' budgets. Thus, external support must be sought.

Stephen White's suggestion of a Particular Program mounted by the Sloan Foundation to help redefine the liberal arts is a promising idea. Such a program would certainly include ways to support development efforts such as those outlined above. It is likely, however, that such a program would achieve its ends more surely if it does not attempt to engage all parts of an institution in a redefinition of its liberal arts goals. More focused programs are needed to assist in the development of ideas and materials. Raising the general question too centrally is likely to lead to endless debate, with highly uncertain prospects for a satisfactory conclusion. It is difficult even now to predict what would have happened at Dartmouth if it had been proposed as a general rule that every student must take computing and mathematics. On the other hand it is easy to predict the chaos that would have resulted if the faculty had been asked to agree that these are a necessary part of any liberal arts program. Change came at Dartmouth not because new general principles were agreed upon but because the mathematics department, led at that time by John Kemeny, developed a time-shared computer system and a number of specific mathematics courses that students found relevant. The students, given the opportunity, moved to embrace new quantitative skills. The faculty followed in due course.

RESPONSE 9

Frederick Rudolph

Mark Hopkins
Professor of History
Williams College

A few years ago in a not altogether puckish mood I suggested that, given the records of all those college football players who made it to the White House, we would have been better off had they been ballet dancers. Now, Stephen White tells us that, in whatever activities their collegiate energies might have been spent, the public servants of tomorrow had better be as comfortable with the computer as we already expect them to be with the range of subjects that now pass as a liberal education. For a number of reasons I find him thoroughly persuasive.

Ever since I first read *The Education of Henry Adams* 40 years ago as a college senior I have been haunted by the degree to which, like Henry Adams, we are all in one way or another destined to inherit one set of values and circumstances, required to grow up with another, all the time preparing for an unclear future that will impose yet another. The anguish felt by Henry Adams, recognizing himself as a child of the eighteenth century born into the nineteen century preparing to equip himself that he might live in the twentieth century, need not be so exquisitely felt or expressed in order to be shared by all of us.

What is unforgettable about Adams' search for some way to make his world comprehensible as well as manageable was his acknowledgment that science had unleashed great energies that man showed little readiness or ability to understand or to control. Rejecting the easy materialism, sentimental equalitarianism, and unexamined belief in inexorable progress with which his contemporaries welcomed new technologies and new sources of power into their lives, Adams concluded that what was needed was nothing less than a new self-conscious intellectual style that was equal to the challenges that he located symbolically in the dynamos that captured his imagination at the great expositions in Chicago in 1893 and Paris in 1900. "Thus far," Adams concluded, "since five or ten thousand years, the mind had successfully reacted, and nothing yet proved that it would fail to react —but it would need to jump."

Can there be any doubt about whether the computer is the instrument that allows and encourages the mind to jump, to respond with courage and imagination to the mysteries and uncertainties that would otherwise lie beyond synthesis, organization, comprehension? Do not misunderstand me: mystery and uncertainty are permanent conditions of human existence, and unless we admit that we cannot know everything or do everything, we are doomed to be miserable. On the other hand, neither can we sit idly by and allow ourselves to be pushed around by our own inventions, overwhelmed by energies and technologies that have independent lives of their own only as we allow them to. The purpose of a liberal education is to make the world comprehensible, to incorporate it into one's being, and surely that cannot be done without embracing the computer and making it the instrument of a greatly expanded capacity of man to analyze and therefore comprehend his universe. The computer permits us to grasp the meaning of great masses of otherwise undigestible data, to extract significance from inert statistics, to impose imaginative analyses on millions of otherwise discrete facts. Literally, the computer allows the mind to jump.

Adams was a historian, but in the presence of the dynamo he received less help from the scientists than he needed. "Men of science," he remarked, "could never understand the ignorance and naiveté of the historian, who, when he came suddenly on a new power, asked naturally what it was; did it pull or did it push? Was it a screw or thrust? Did it flow or vibrate? Was it a wire or a mathematical line? And a score of such questions to which he expected answers and was astonished to get none." In the meantime, without answers and without the computer, Adams fashioned other tools of analysis and attitudes of mind—intuition, skepticism, a sense of paradox and ambiguity, a sense of proportion, even of beauty and value—into a most remarkable instrument for analyzing his world.

But how he would have enjoyed the computer! And the work of the quantitative historians, the practitioners of cliometrics who may indeed be fashioning "a technology of history," an analytic style that allows the historian to think with "enormous new efficiency." Surely we should prefer history based on informed generalizations rather than uninformed guesses, and that is the precise difference between history that grows out of the data analysis allowed by the computer and history that has no other way to subject myth, tradition, and faith to analytical scrutiny.

For historians, as Stephen Thernstrom and his followers have clearly demonstrated, the computer has created a frontier with large possibilities and, unquestionably for some years to come, a battlefield as well. Thernstrom enables us to understand the dynamics and realities of social mobility in ways previously denied us; without the computer, he would, in the face

of certain important questions, be as mute as the generations that came before him. Whole areas of historical study once thought to have been comfortably comprehended and therefore more or less put to rest by generations of soundly trained scholars — class structure, slavery, federal elections, immigration, westward movement — will, thanks to the computer, have to be brought back to life. A generation that thinks with the computer will have access as never before possible to the movements of people in and out of schools, farms, cities, polling booths, tax records, and bank accounts. The computer gives us new access to ourselves, a new hold on our identity as a people.

At the same time, let it be understood that the historian at the computer, mining his data with the eagerness and energy of a '49er in the goldfields of mid-nineteenth century California, is not to surrender those other tools of analysis — imagination, intuition, skepticism, a sense of paradox and ambiguity — that have thus far admirably served and shaped his analytical competence and comprehension. Yet, of course, the Sloan Foundation is not about to launch a "Particular Program" in order to save the historical profession from obsolescence. On the other hand, if I read Stephen White correctly, it foresees a future in which whole generations are trained to know what they ought to expect from historians equipped with the analytical skills that accompany a competence with computers.

The times are ripe for a "Particular Program." In reaction to the curricular disarray of recent decades, we are witnessing a yearning for tidiness, order, and discipline in the course of study. There is widespread concern over what ought to be considered essential to a liberal education and some sense of wonderment both at what has fallen out of the curriculum and at much that has taken its place. A revolution from the outside may indeed be rewriting the course of study. Can the computer really be ignored? Can foreign language illiteracy last much longer? How long before the television network news analysts and even the Secretary of State will be expected to understand the Constitution of the United States?

But, if the times are ripe, so are the professors entrenched, nervous, defensive, self-protective. And even as we applaud the proposal that the computer be added to the second law of thermodynamics and Shakespeare in the experience of an educated person, we must acknowledge that neither Shakespeare nor Josiah Willard Gibbs are as curricularly secure as they once were. Even so, a Particular Program designed to support "The New Liberal Arts" deserves widespread encouragement.

In some ways Stephen White's paper is reminiscent of countless now forgotten essays imbedded in the remains of early nineteenth century undergraduate literary societies and journals: pleas for a recognition of the

legitimacy of belles lettres as a domain of liberal learning, bold inquiries as to why and by whose authority history stopped with the ancients. Liberal education has undergone revolution before, and always from the outside: nineteenth century students were studying nature, exploring the application of science to the work of the world, paying serious attention to art and music — as well as history and literature — before academic authority recognized that the curriculum was in the process of being redesigned, its content revolutionized, from the outside.

The importance of Stephen White's paper is that while the need for change is just as pressing as it was when students created the counter curriculum that in the end carried the day, students cannot set up computer terminals as readily as reading clubs and nature museums, nor can they be expected to pull down the barricades that a well entrenched professoriate has erected against change. Does anyone believe, for instance, that postponing retirement to 70 and beyond is a way of encouraging innovation in the course of study? Or that computer technology will quickly commend itself to scholars who earned their doctorates without even the benefit of a Xerox machine?

The Sloan Foundation is going to need a great deal of help in pressing its case, for, among other things, at a time of emphasis on austerity and energy costs, it is inviting higher education to accept expensive new commitments. Presidents and academic deans of extraordinary political skill and persuasiveness will be essential to implementing the purposes advanced in the Sloan proposal.

It does seem to me that in arguing that its aims must be "organized in terms of the liberal arts colleges and not of the separate disciplines," White may be overlooking a natural, appropriate, and perhaps even necessary ally. For, if it is true that the professors are entrenched, nervous, protective of their turf, perhaps one avenue toward curricular reform is to strengthen the disciplines, beef up the academic majors, explore the ways in which they can be enhanced as intellectual experiences by making room for training in the analytic skills and technological literacy that a computer component would encourage.

Why not reorganize the history major, the government major, the economics major, as well as sociology, anthropology, psychology, and the various interdisciplinary groupings (American Studies, Black Studies, Women's Studies) so that every major will have taken a course that is responsive to the urgent message of the Sloan paper? While the emphasis on the undergraduate major, the element of concentration in the course of study, has long been held responsible for the weakness of the component of general learning in a liberal education, my impression is that in recent

decades the major has to a serious degree been weakened and deprived of coherence. Strengthening the major may not at first seem the most appropriate way to strengthen general education, but surely there is, for instance, not a history major in the country that would not in fact be strengthened by a computer component, a comparative culture requirement, and a foreign language competency.

The analytic skills and technological literacy for which this paper builds a most persuasive case can be achieved through required programs in general education, in which various modes of thought or approaches to knowledge become curricular requirements imposed on all students. And surely the secondary schools must be brought around to recognizing their responsibility to adhere to a basic core of learning as a foundation for college work. It would be a mistake, however, to tie the destiny of the Foundation's intentions to any one formula, any one curricular prescription, any one high school program. Rigid definitions of curricular truth are vulnerable. General education (with a computer requirement) will make its way in some places and not others. The purposes of the Harvard, Chicago, and Williams course of study are the same, but the styles are different, and the style of an institution is both fragile and worthy of respect, as long as it is sensitive to social and intellectual change and able to accommodate itself imaginatively to its own perceptions of those changes.

In suggesting that courses in applied mathematics "must be seen to lie at the heart of the curriculum, and must make the same claim on the college as a whole as courses in philosophy or government or literature or languages," White is really advancing a rather modest proposal, given the great intellectual energies that the computer is capable of both harnessing and releasing. When Lewis Thomas assures us that we do not understand a flea, let alone the making of a thought, he is not excusing us from trying. Indeed, that is our fate, our particular uniqueness as human beings. The computer is now among us. We must not only try to understand it but make it an instrument of our understanding.

RESPONSE 10

Richard Warch | *President*
Lawrence University

"The New Liberal Arts" is, in the main, a prolegomenon to a yet unfashioned program. Its principal argument is unexceptionable, although the title is essentially misleading. For what this essay proposes need not — and probably should not — be construed as "new" liberal arts *per se*, but as a new mode of teaching and learning in liberal education. The distinction, which is acknowledged in the paper, is fine but important. Teachers at liberal arts colleges, as John Highet put it, have as one of their roles that of "anchors in the midst of a tempestuous sea of change." Thus, many of the intentions and aspirations of a liberal arts college and the curriculum that conveys them must be held constant. Questions of value and taste, issues of culture and the arts, and matters of historical and literary record have abiding merit and a respected place in liberal education. The "old" liberal arts may be refreshed by "new modes of thought" but they will not be replaced by them. History, for example, is more than cliometrics. Simply put, there are a number of ways of perceiving the world "and the way it wags" and it would be an egregious error to subsume them all to the various emanations of technological skill.

That disclaimer, however, does not obviate the principal thrust of White's essay. In short, the computer — and the analytical and technological skills that it represents — constitute the most important challenge faced by the liberal arts college in modern times. Unlike technological advances in the past, this machine cannot — and will not — be relegated or delegated to the select few who will use it directly. Its impact and influence affect us all and inform our living and our thinking in ways that we must comprehend and control. In many ways, the computer is the symbol for our age. It has created — as well as reflected — a climate in which data, statistics, and their manipulation shape the way in which we understand issues and problems and how we reach decisions regarding them.

White is wholly correct in his assertion that liberal arts colleges (and their students) must come to terms with the computer. And he is right in arguing that by so doing colleges and students will perforce come to terms

also with the applied skills of the quantitative literacies. How this worthy and necessary end is to be achieved is the central problem, for to do so properly will require a concerted effort across the disciplinary and divisional boundaries that demarcate the liberal arts curriculum. That is not to say that the computer and quantitative literacies will or should inform the entire curriculum; it is to say that they will and should be integrated with a significant portion of that curriculum. Effecting *that* result is the challenge posed by White.

His essay clearly states the broad reasons why such sweeping change is mandated. For computers embody a technology, perhaps the only technology, having an important *direct* influence even on those undertakings and disciplines traditionally regarded as non-technical. This singular fact shapes the way in which we must approach the place of the computer in the liberal arts curriculum. The crucial concept here is integration. Philosophically as well as pragmatically, any other approach will violate both the nature of liberal education and the particular genius of the computer. Liberal education is not conveyed through a curriculum that is prescriptively vocational; it does aspire to provide acquaintance with and to promote mastery over various modes of thought. Since quantitative literacies and computing are pervasive modes of thought and application that transcend both disciplines and vocations, it is thus appropriate that we mesh computing with liberal education, that we have computing permeate parts of the curriculum, rather than add computing to the curriculum as another element of it.

I should make clear—if it is not already—that my response to White's essay is predicated both on my view of the liberal arts college and by the way in which Lawrence University has sought to define its future course in computer use. Perhaps, then, it is best to state at the outset what ought *not* be the objective of the liberal arts college and, by extension, of a Sloan Foundation program. We should not seek to develop departments of computer science, staffed by computer scientists who will offer courses in computing and about computers—even if they were to do so for all students. Not only would the recruitment and retention of such specialists be prohibitively expensive (in light of the disparity between academic and industrial pay scales), but it is also likely that such specialists would have little appreciation for or commitment to the larger purposes of the liberal college. Of more importance, however, is the fact that such a department and staff would impede and delimit the proper place of computers in a liberal arts curriculum.

The place of computers within the liberal arts should not be viewed as just an addition to the offerings of a liberal arts college in the way that one

might add German or art history (were they not already there). Computers must instead be introduced more in the way one would introduce the library (again, were it not already there). As with the library, the computer is a resource that must be available to all students for the conduct of their disciplinary studies, and it is incumbent upon the institution to provide training of several sorts that will help students learn to use the resource — library or computer — for these studies. Only incidentally will this training provide the background for some few students to pursue library science or computer science professionally, but in neither case should the training available at a liberal arts college be expected to substitute for the specialized training that these students would subsequently pursue in appropriate professional schools. The creation of a Department of Computers (or whatever one calls it) that offers courses and a major is therefore not likely to be the most appropriate way to introduce computers to a liberal arts college.

Given that broad premise, we need to consider programmatically how best to create an environment at the liberal arts college permeated by the computer in the way that it has long been permeated by the library. The computer-library analogy is useful, I believe, but cannot be carried too far. The computer poses special problems that will require special attention. In the main, there are three areas that will command that attention: faculty development; curricular innovation and change; and hardware acquisition.

Of these, faculty development — to use a much-abused term — must be considered the first priority. An all-pervasive program of the sort envisioned here must evolve out of the total instructional staff rather than be assigned to a few computer experts. The latter strategy — with or without a Department of Computers — would have the consequence of relieving the college faculty of responsibility for helping students learn to use the computer for scholarly work in whatever discipline the student elects to pursue. The faculty of the institution as a whole must become computer literate even as — preferably before — the students do so. For the most part, this effort will involve the offering of extensive training opportunities for present faculty. These opportunities will, of necessity, cover the gamut from introductions to the computer and learning computer languages to writing programs and designing computer-dependent (at least in part) courses in the several disciplines. The goal must be to infuse computer literacy and application throughout the curriculum through the faculty in the disciplines.

If we assume that broad-based faculty development is the prerequisite to success in this venture, we must also ask who will lead these faculty toward the promised land. Here again, I believe, the college should look

for leadership from within its own ranks. Not only will such leaders be hard to find in the marketplace, but the best person to spearhead a pervasive curricular effort of this sort is likely to be an academically trained individual who has participated in the teaching mission of the institution. Identifying, preparing, and assigning such a person to take on this responsibility must be a principal focus of the college's commitment; enabling a college to undertake that process would obviously constitute one element of a Sloan program. The use of consultants and participation in seminars and workshops can effectively complement and supplement the work of the faculty leader, but in the absence of such a leader an ambitious program of change — White calls it both evolution and revolution — will fragment and falter.

Personnel matters are, of course, but the precondition to the essential aspect of the effort: curricular innovation and transformation. These must be of two related but distinct sorts. First, though of secondary significance, are courses introducing the computer itself and computer languages. Such basic (no pun intended) offerings constitute the technical competencies (programming, algorithmic thinking) that — though of intrinsic interest and value — provide the underpinnings for the truly innovative and integrative work of curricular revision in the disciplines.

Second, then, we must create and offer courses that help students to develop habits of thought that will permit them to think ultimately in computerizable ways. Certainly computer languages provide a compact, unambiguous way to express computerizable approaches to problems, but the coding of the approach in a particular computer language is trivial once the strategy itself has been carefully thought out. Such strategies, however, can be taught effectively only in the context of disciplinary studies in regular courses in the curriculum: courses that present computerizable approaches to the material on a par with more traditional approaches. Thus, one needs to foster a pervasive utilization of the computer throughout the curriculum as a whole and in so doing at the same time foster quantitative literacy. Problems of research and analysis employing the computer and quantitative skills should then become one mode of teaching and learning in the disciplines, in economics and in history, in music theory as well as biology.

Creating and revising courses will necessarily, I think, provoke further innovations in both instructional materials and methods. Without such innovation, the infusion of the computer in the curriculum will vitiate the very purpose it is intended to serve: the understanding and use of computing in the context of liberal education. In short, it is unrealistic to expect that students will be able to learn and use computing if they must rely

solely on formal class instruction at every step of the process. And if faculty at a liberal arts college were to assume that obligation in its entirety, they would probably devote more time to means than to ends. Returning again to the analogy with the library, it can be argued that the principal task is to *use* the resource. But since the ability to use the resource of the computer is not yet a given (as it is, by and large, with the library), the student must acquire that ability. And new materials and methods must be devised to help him do so.

Course development, then, must be accompanied by the development of supporting instructional materials of all sorts. Manuals are inadequate learning tools here because they enumerate capabilities without offering much guidance in exploiting those capabilities to accomplish particular tasks. Rather, colleges need to develop text materials, computer-presented tutorials, pre-recorded videotape demonstrations of hardware and of solutions to representative exercises, written discussions of such solutions, and the like. A variety of such resources, prepared by faculty and linked to the academic program of the college, will permit individual students to choose those resources that speak best to their own learning habits and to the particular needs of their disciplinary applications of computers.

As with materials, so too with methods. Any college that has offered computing has probably experienced excessively large enrollments in those courses. Given both staffing limitations and a decision to infuse the curriculum with computing, the pressures can become severe and the pattern of computer use uneven. A better program would include the design and implementation of instructional methods whereby at least some students could take the bulk of the instructional responsibility upon themselves through self-paced self-study. Thus, the college should provide learning resources of a variety of sorts with detailed statements of expectations; advanced students could be enlisted to provide tutorial assistance for their fellows. Suitable proficiency tests that would monitor the individual's progress could be the means by which a student demonstrated literacy in a given area. Such methods should be restricted to courses in computing *per se*, thereby relieving faculty to devote themselves to computer-related courses in the disciplines.

Finally, the college that embarks on a program of these dimensions must recognize that developing new courses, inventing new forms of instruction, producing learning materials, and enhancing faculty expertise in computing will result — if successful — in demonstrable needs for more computer hardware. Here again, the library analogy is useful. A first-rate liberal arts college library has at least two characteristics: it has a strong collection of resources and it is accessible seven days a week. The computer

must share those characteristics. Thus, expanded mainframes and additional terminals will be necessary ingredients — or consequences — of a curriculum permeated by the computer. Although developmental activities properly should be the focus of efforts to integrate computers with liberal education, these efforts will wither if support for the acquisition of hardware is not included in the program.

I have chosen here to sketch out three broad areas to which any effort to realize White's ambitions must be attentive. It has been a programmatic response, to be sure, but it is a program that the Sloan Foundation is contemplating. Of the three topics in White's essay—applied mathematics, technological literacy, and computers—the last is certainly the most appropriate for the liberal arts college. I think it is fair to say that the computer will—indeed, has—come to the liberal arts college without the intervention of the Sloan Foundation. But its coming is fraught with two principal hazards: that the computer will become simply the special province of those who choose *it* as the focus of their education, and/or that it will be perceived as offering the one avowedly vocational skill available in the liberal arts curriculum. To permit either of these hazards to be realized — by inattentiveness or inability — will be to miss a great opportunity.

To seize that opportunity, however, is a major undertaking. It will indeed "require an enormous amount of curricular invention." It will also require a significant degree of institutional commitment and persistence to effect the fundamental changes that will be needed. But liberal arts colleges are *the* right context for that effort, for their traditional intentions and this opportunity can and should be complementary.

In seeking to generate momentum for that effort — as opposed to trying to initiate it — the Sloan Foundation must look in the first instance to those institutions that have already made a substantial start in several of the areas to be affected by the project. The faculty must already be receptive to its crucial role in the overall activity, the institution must already have made some progress in thinking about the integration of computers in its curriculum, and a significant part of the necessary facilities must be in place. Most important of all, a program of support must recognize that the mere creation of a spectrum of computer courses as an addition to present offerings is not enough. We should seek no less than the creation of an environment at the liberal arts college in which the computer stands with the library in service to the teaching and learning mission of the institution. We should set our sights on achieving a major reorientation and enrichment of liberal education that will not only accommodate, but will embrace, both the computer and the modes of thought that it employs. If we can achieve those ends, the liberal arts college will have succeeded in educating civilized adults possessing both acquaintance and experience with the modes of thought represented by analytic and technological skills.

AFTERWORD–

STEPHEN WHITE

I begin this afterword on a positive note, deferring until somewhat later the exercise of my prerogative to become testy. I am of course gratified that the general view expressed in the comments upon my tentative essay is very much supportive. At least nine of the 10 who troubled to write appear to believe that liberal education, whatever it may be, would do well to invite an infusion of education in analytic skills or technology or both, pretty much as I defined them, and that for the purpose of providing such an infusion the computer is an instrument not to be scorned. One commentator, Jacques Barzun, may be supportive or may not be; I find it difficult to determine which on the basis of his comments.

I am even more pleased that four of the 10 who contributed had positive suggestions as to what might actually be done about all this, although no two hit upon exactly the same suggestion. At this stage of what I conceive to be an inquiry such diversity of views is as it should be.

One of those suggestions, from Rudolph, comes quite close to what was in the back of my mind when I wrote the paper, although I tried to be careful not to let it intrude. I quote his salient sentence: "Why not reorganize the history major, the government major, as well as sociology, anthropology, psychology and the various interdisciplinary groupings . . . so that every major will have taken a course that is responsive to the urgent message of the Sloan paper?" (I assume with great confidence that the word "course" in that extract is used in the general and not the curricular sense.) I feel in my bones that this is the right way to go, but I don't have that much faith in what my bones have to say and I am certain that the matter requires a good deal more consideration than I and perhaps Rudolph have applied to it.

A somewhat similar suggestion comes from Caws, although the manner in which he chose to phrase it fluttered the dovecotes of my mind. Again I quote: ". . . there exists a more fundamental set of disciplines — as seen from the point of view of the learner — than either the sciences or the humanities, namely the social sciences. The resulting curriculum would

be based on introductory material in anthropology and linguistics, perhaps some sociobiology and sociology of knowledge, some history of science, designed to acquaint the student with the mode of insertion of the human into the natural world, the resources of the mind, and the constraints of the environment which made it first possible and then necessary to count, to measure, to calculate." With some stretching, this can be construed to mean at least part of what Rudolph intended. Caws, however, appears to flinch at the thought of introducing technology. He recommends that students "study the abacus as a primitive cash register" as a means of opening the way to "understanding the computer without representing it as a bit of high technological magic." I am not certain what that sentence means, but I am fairly certain that whatever it means is wrong, and the association of technology with magic, however it was intended, is misconceived.

Morison's suggestion is another thing altogether. It is well worth extended quotation:

> Somewhere in their course of study . . . they should become engaged in the unfinished business in the outlying society — the problems not yet solved, the questions not yet answered, the opportunities not yet followed through. Topics in these categories come in all shapes and sizes — posed by the new means for procreation, for the exploration of outer space, for the manufacture of energy, for the production of novel goods and services. Entangled with them are such various sub-topics as the nature of work and the work-place, the university as a profit center, the possible limits or limiting of enquiry.
>
> They all have their origin in technology — genetic engineering, nuclear reactors, the shuttle, servomechanisms and the computer, for instance. But they all lead out to every corner of human endeavor — economic arrangement, political structures, institutional design, communication networks, social organization and the condition of individual lives. They also raise for review the timeless concerns — the relation between thinking and doing, the boundaries of appropriate scale, the proper claims of aesthetics and the difficulty of choice among both practical and moral considerations . . .
>
> In such study the nature of an organizing principle for a truly modern liberal education will become clear — what one needs to know to understand the new situations existing in society and to reach resolving decisions on what to do about them.

This is radical enough, I think, to send tremors through the liberal arts establishment if they had reason to believe it was about to happen to them. It seems to me to make great good sense; the question that must be asked is whether it lies within the bounds of possibility.

That question at least does not arise in Kreider's paper, in which he offers a suggestion in the form of a straightforward account: "Change came to Dartmouth not because new general principles were agreed upon but because the mathematics department, led at that time by John Kemeny, developed a time-shared computer system and a number of specific mathematics courses that students found relevant. The students, given the opportunity, moved to embrace new quantitative skills. The faculty followed in due course." Indeed, Kreider's paper and Morison's seemed to me to express nearly identical themes approached from quite distinct viewpoints; they complement each other beautifully.

Finally, Netzer offers no prescriptive advice at all but instead a general principle: the Law of Irretrievable Loss. It seems to me that he has provided a criterion against which all post-secondary education (including vocational education, whether in medicine or TV repair) should be measured. I do not mean to suggest that each and every element in formal post-secondary education should meet that criterion, and I don't believe Netzer means to suggest so, but I think we both mean that his Law should be taken into consideration whenever curriculum is scrutinized and that the curriculum as a whole should conform to his principle. Certainly it is a principle which adds force to my own essay, but it doesn't move the underlying problems any closer to solution.

So much for harmony; now on to the merrier business of discord. I was troubled more often than I liked with recurrent expressions of disagreement with statements I had been careful not to make. Feet were stamped in opposition to courses in "The Theory and Practice of Computing"; nowhere in the paper did I so much as allude to such courses, much less urge them. It is not that I oppose such courses. I simply do not know whether they will be either sufficient or necessary for the ends I have in mind. Neither was I making any kind of appeal for courses to be labelled or construed as "general education." I have never known exactly what such courses are intended to be or intended to accomplish. (Merely in passing, however, I feel free to say that courses called "Physics for Poets" appear to me to reflect contempt for physics and contempt for poets.) Indeed, as far as I can find, I virtually never alluded to "courses" at all; the word appears only twice in the entire paper, both times in the same sentence and in an entirely neutral context. I did write of "curricular change," but that is a somewhat different matter.

I was careful, as many of the commentators were not, to make a clean distinction between science and technology, between mathematics and applied mathematics. There are intimate linkages among them all, but the shortcomings I thought I perceived in liberal education lay in the applications and not the pure disciplines, and indeed a good many liberal arts colleges do quite nicely in science and mathematics. Of course, a good many do not, and one could very likely write an irritating little paper on that subject. It was not, however, the subject I was dealing with.

Whether applied mathematics and technology are to be called "new" or "old" liberal arts doesn't appear to me a very important issue. I chose the title as I did in part because I hoped it would be provocative, which it turned out to be, and in part because I do not recall that applied mathematics as distinct from mathematics, or technology as distinct from science have ever before figured in the idea of a liberal arts college. I suspect that millenia back arithmetic was taught in the spirit of applied mathematics because there was no practical way of avoiding it, and possibly some scholar might make the case that Pythagoras taught music as applied mathematics, or possibly applied music as mathematics. But that is going a long way back to pick a small quarrel, and doing it the hard way as well.

There are in some papers details which offer tempting targets. Caws, for example, derives some kind of comfort from the fact that the Romans employed letters of their alphabet to serve as numerals and hence a man who was termed *litteratus*—"lettered" was a mathematician *ipso facto*. (I am reminded of von Neumann's claim that he knew all the numbers in the Manhattan telephone directory and all that remained was to match them up with the names.) It would be more accurate to say that the Romans, faced with the problem of multiplying CXIV by MDXII, wisely gave up the most fruitful portions of mathematics entirely, and it was very nearly two thousand years before a serious start was made upon them.

I was subjected to etymology by Barzun as well. (My own dismissive reference to etymology in the paper may have raised humanist hackles.) I enjoy etymology: it is a fascinating game. If one is a student of the evolution of language, it is something a good deal more than a game. But I cannot be brought to believe that in the general run of affairs a knowledge of Indo-European roots adds very much to a discussion or to the progress of an undertaking.

The Barzun paper as a whole I found somewhat baffling. It is an elegant paper, full of interesting things. But each time it appears about to contribute to the present discussion it wanders off into a discourse on junk mail or long lines at National Parks.

Both Barzun and Caws (without collusion, I am sure) saw fit to read me a lecture on Pascal, who was an extraordinarily fine mathematician and an extraordinarily fine prose stylist. I cannot, however, find anything in Pascal that bears directly upon the issues under consideration here. To be sure, Pascal spoke of the *esprit de géometrie* and the *esprit de finesse*, but he was talking about people and the spirit by which their thinking was animated, and not particularly about what they were thinking about. Judging from what he actually wrote, he would have been quite prepared to acknowledge that *géometrie* itself, as a subject of thought, could be quite profitably approached with the *esprit de finesse* as indeed it originally was.

What he actually did write is interesting enough. I do not attempt to translate from his own seventeenth century French, for a translation would be most misleading, but here is a casual adaptation of his own words which seems to me to be faithful to his intent:

> All the mathematicians would possess the refinement of humanists if they bothered to look around them, for they do not draw false conclusions where they understand what they are talking about; and the best of the humanists would be mathematicians if they could concentrate their attention on the unfamiliar elements of mathematics.

(I am aware that my "casual adaptation" departs significantly from the canonical translation. In particular, "finesse" has generally been translated "intuition"; the broader notion of "intuitionism" stems at least in part from Pascal and has a history of its own. As I have said, I believe that such a translation is misleading, and moreover that in this instance the use of the French words in an English text is impermissible, but that has more to do with the proper use of language than with this afterword.)

All in all, I would venture to bet that Pascal would have considered it self-evident, even three-hundred-odd years ago, that a little mathematics was likely to be useful whatever one set out to accomplish. He himself was interested in betting, and even went so far as to apply the mathematics that he had first associated with wagering to help him arrive at an agonizingly difficult personal decision. Having made his calculation, he abandoned mathematics altogether and flung himself upon the bosom of the Almighty, having deduced that to do so was his best bet. He was also the remote forefather of the computer. So much for Pascal.

But I, too, am yielding to irrelevancy. Let me provide a summary, part abstract and part apologia. In these last decades of the twentieth century, a cultivated man should be aware of the mode or modes of thought rep-

resented in analytic skills and technological skills. Such an awareness is consistent with a liberal education, and perhaps even a necessary aspect of a liberal education. It meets the idea of a liberal arts college, and the fact that the idea of a liberal arts college is not as well embodied in existing colleges as it might be has very little to do with the matter one way or another, except perhaps as it makes the task more difficult.

For the rest, I go back to Warch's admirable essay. With some of it I disagree, and I would have liked it to have been a little more substantive and a little less procedural. But I find no fault at all with his opening sentence: " 'The New Liberal Arts' is, in the main, a prolegomenon to a yet unfashioned program." Neither Pascal nor I could have said it better.